May 5, 2017 city water pressure drop
By Matt McBride, October 27, 2017

Introduction

In the early evening of Friday, May 5, 2017, New Orleans east bank city water pressure experienced a severe drop due to the simultaneous failure of two of the four water distribution pumps operating at the time. Prior to the pump losses, east bank city water pressure as measured at the High Lift control room in the Sewerage and Water Board's Carrollton Water Plant was 66.5 pounds per square inch (psi). Following the loss of the two pumps, it dropped to 23 psi. Water pressure was partially restored after approximately ten minutes, and fully restored approximately 80 minutes later.

The pressure loss was reflected at numerous remote Sewerage and Water Board sites across the east bank. Pressure transducers located in five of these sites recorded pressures below 15 psi, the state-recommended threshold for issuance of a precautionary boil water advisory. Transducers at two other sites recorded pressures within 2 psi of the threshold. Analysis of the transducer readings shows that data at two of the five sites which recorded sub-15 psi pressures was likely representative of water pressure in the surrounding neighborhoods.

No precautionary boil water advisory was issued May 5, 2017.

A review of the events of May 5,2017, as well as other low water pressure events through 2017, reveals systemic gaps in the monitoring of city water pressure and the alarm scheme used to alert personnel to a low water pressure condition. Questions also exist regarding the quality and use of data by Board decisionmakers during a low water pressure event.

This report documents the events of May 5, 2017 based upon the primary documents generated that day. These documents include both paper records and electronic archives. In addition, operational logs and electronic archives for all of 2017 from the following facilities were reviewed for insight into possible challenges facing the east bank water distribution system:

Powerhouse and High Lift
Claiborne pumping station
Panola pumping station
Central Control
15 drainage pumping stations

While no secondary documents such as after-action reports were reviewed, it is known that at least one such report exists.

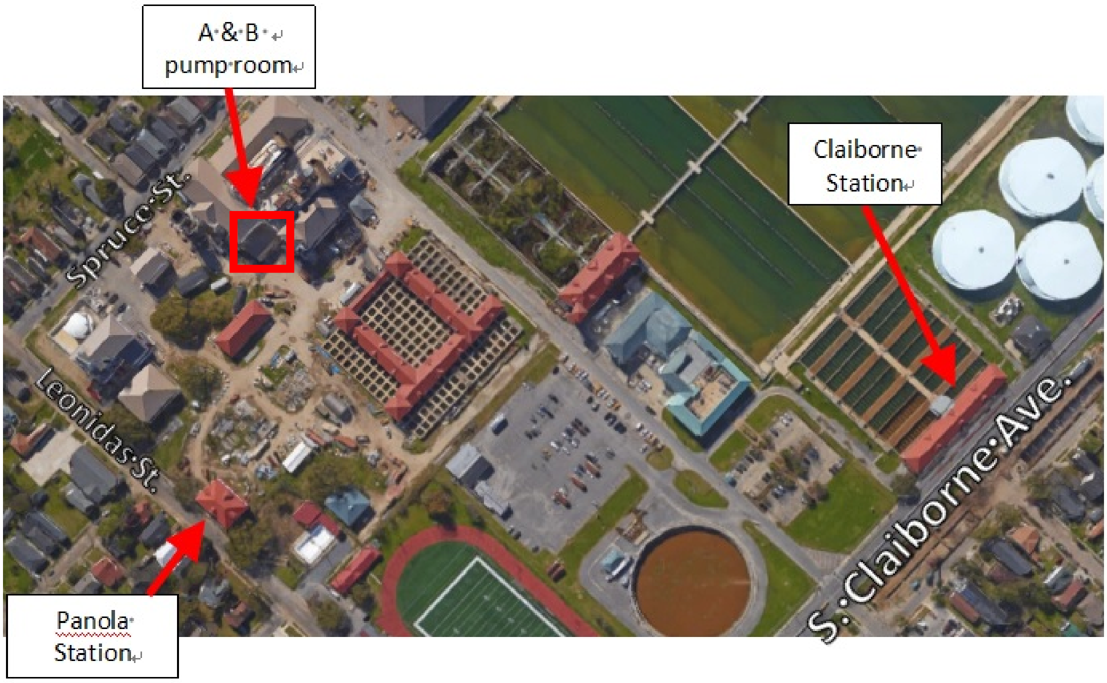
This report builds outward, working from a bare chronology and explanation of the May 5, 2017 pressure drop event particulars, to a description of how such events are monitored, and then to how the event was felt across the east bank, including a detailed discussion of the five locations with pressure readings below 15 psi. A survey of other major pressure drop events in 2017 was compiled for context. Finally, conclusions and recommendations are presented.

Please note that for the purposes of this report, local times from logs are used sparingly and often with qualifiers. Due to the multiplicity of clocks at different locations across the system and their lack of synchronization, event times do not match up across various logs. Durations of events and magnitudes of pressures are considered more trustworthy than individual timestamps.

Water distribution basics

The Sewerage and Water Board operates eight water distribution pumps at the Carrollton Water Plant to provide potable water to the east bank of the City of New Orleans. The pumps are located in three different facilities:

Powerhouse: pumps A and B
Claiborne Station: Claiborne pumps 1 through 4
Panola Station: Panola pumps 1 and 2



Locations of water distribution pumping stations within S&WB Carrollton Water Plant

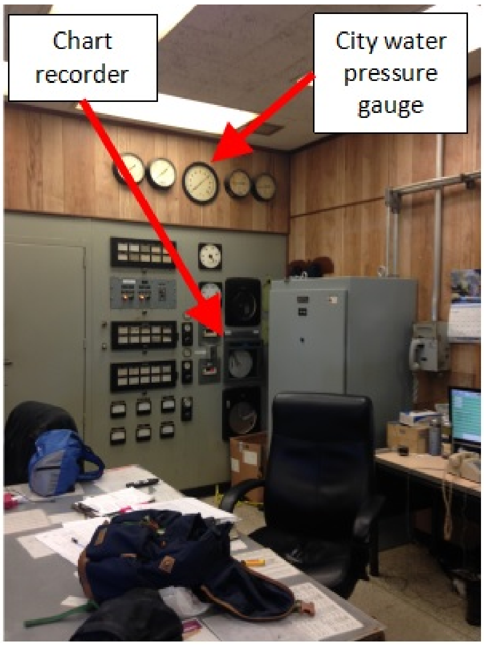
The six pumps at Claiborne and Panola Stations are electrically driven. At Claiborne Station, pumps 1 and 4 run on 25 cycle power, while pumps 2 and 3 run on 60 cycle power. Each pump at Panola station has two motors, one 25 cycle and one 60 cycle. Pumps A and B at the powerhouse are driven not by electric motors, but by steam turbines.

Pumps A and B are primary pumps; in 2017, B pump has run at least part of every day and A pump has run during every day but one. Claiborne Station pumps are "swing" pumps, switching on and off with demand or for other operational or maintenance reasons. The pumps at Panola Station were traditionally considered backup pumps, and were hardly used during the first half of 2017. However, power and pumping problems in the second half of the year have forced the Panola pumps into much heavier service.

On the afternoon of May 5, 2017, four pumps were providing city water pressure on the east bank: pumps A and B in the powerhouse, and pumps 3 and 4 at Claiborne Station.

Chronology: May 5, 2017

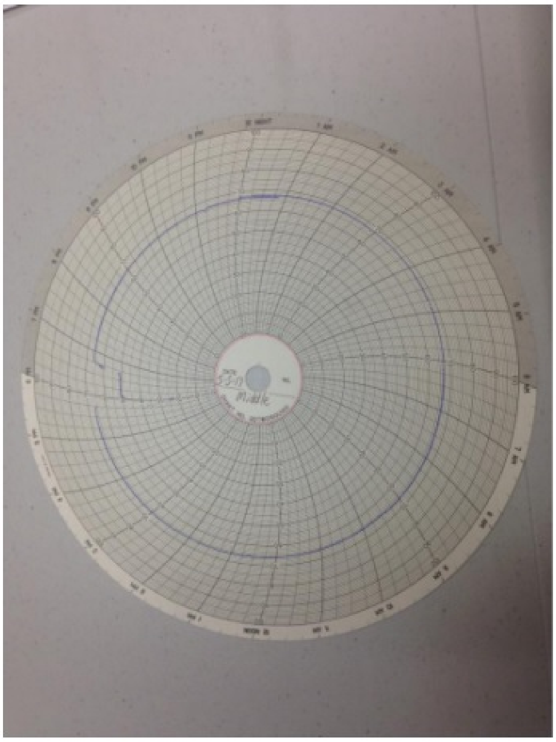
Around 5:40 PM on May 5, 2017, both water distribution pumps A and B at the Sewerage and Water Board powerhouse shut down unexpectedly. With the loss of the pumps, city water pressure fell from 66 psi to approximately 23 psi as measured at High Lift on the Carrollton Water Plant. City water pressure is recorded, among other places, on a chart recorder in the High Lift control room:

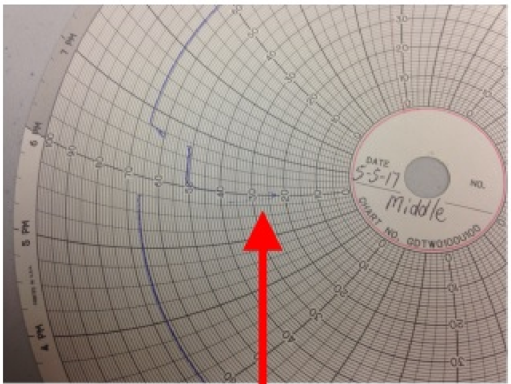


High lift control room in S&WB powerhouse

Chart recorder:
City water press. (blue), steam press. (red)

That chart recorder memorialized the water pressure drop in ink:

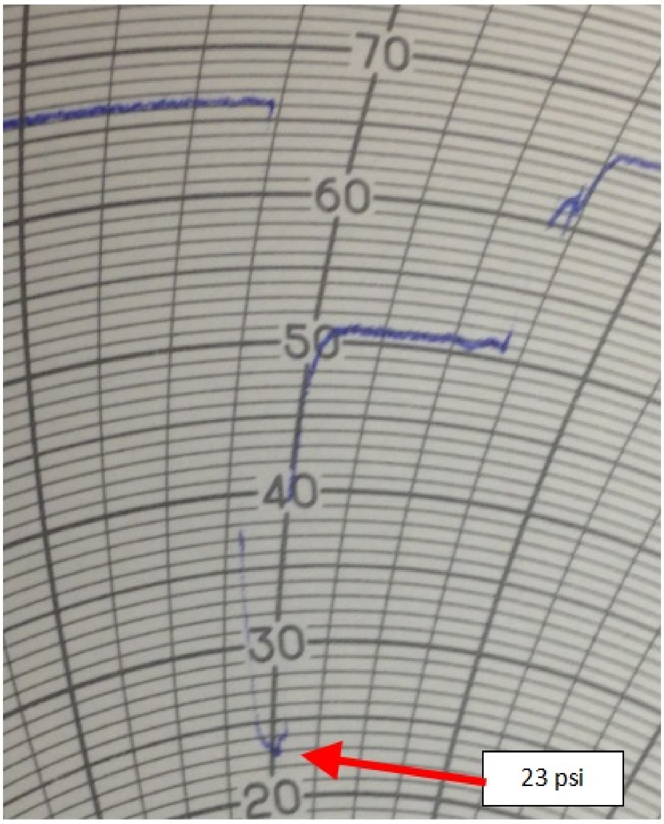




City water pressure drop due to loss of A and B pumps

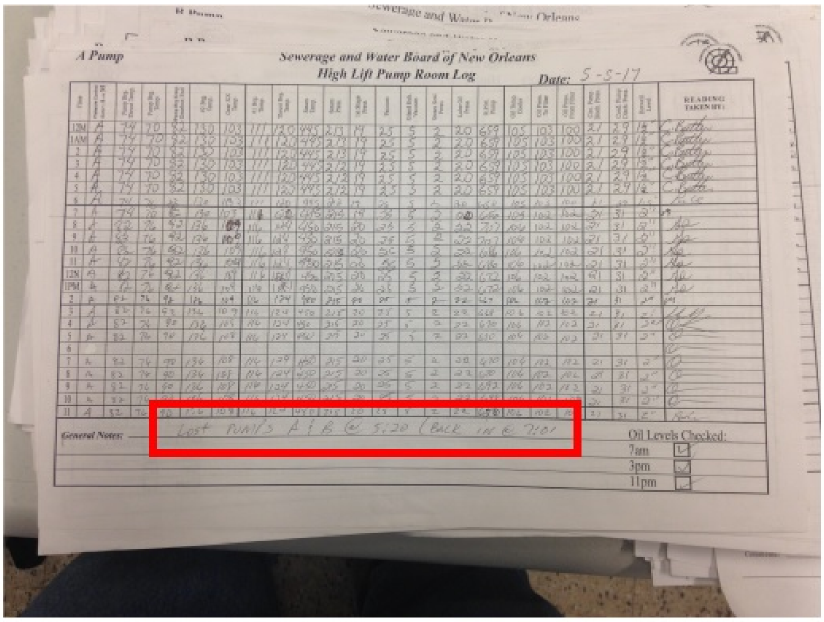
May 5, 2017 chart from High Lift city water pressure chart recorder

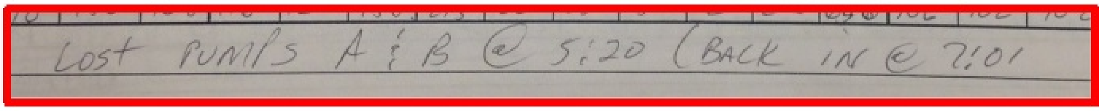
Here is an enlargement of the relevant section of pen trace from the May 5 chart:



Enlargement of May 5, 2017 chart from High Lift city water pressure chart recorder

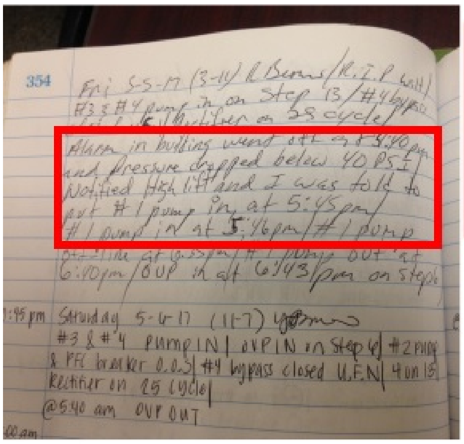
The loss was also noted on the written data logs for A and B pumps. The data logs are on a double sided sheet of paper, with A pump on one side and B pump on the other. The note was on the A pump side:

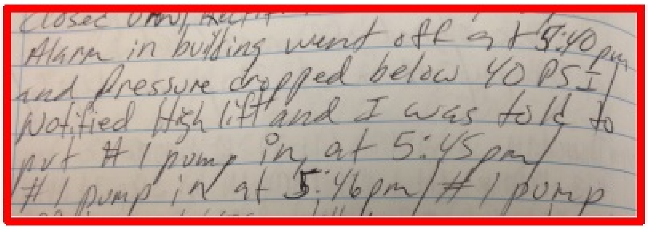




Pump A data log from May 5, 2017

Soon after the pressure drop, the High Lift operator spoke with the Claiborne Station operator. At the time of the loss of pumps A and B, pumps 3 and 4 at Claiborne Station were also running and pumping. This status is referred to as "in." Since two pumps alone are not enough to maintain adequate city water pressure, pump 1 at Claiborne Station was put "in" at 5:46 PM, according to the Claiborne Station clock. This is shown in the written logbook kept in Claiborne Station:

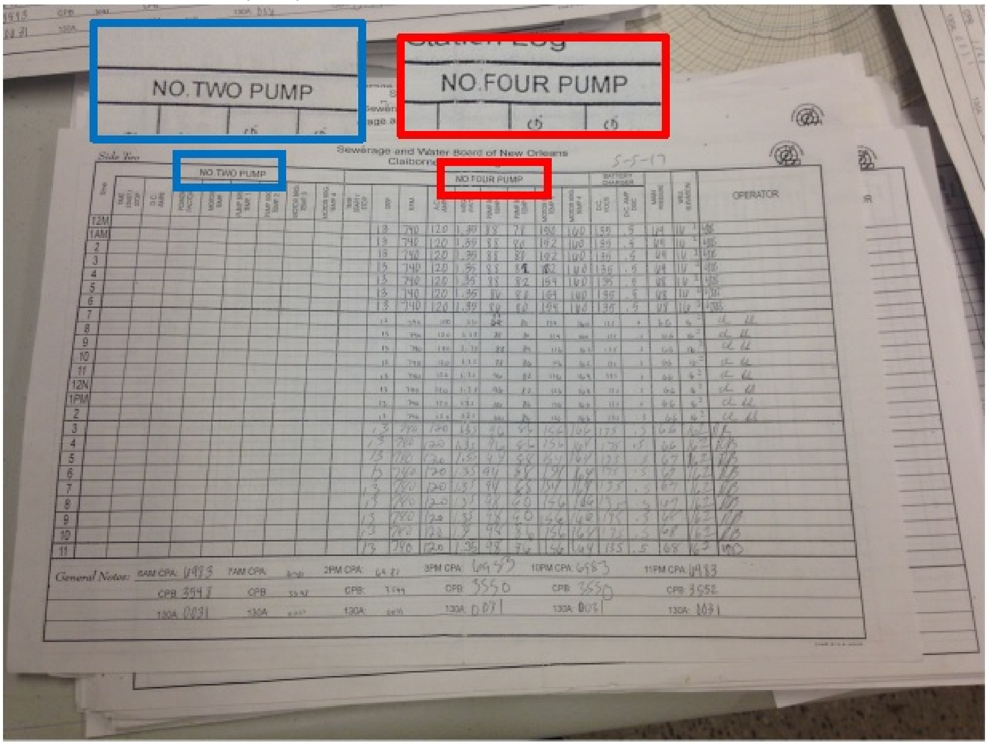




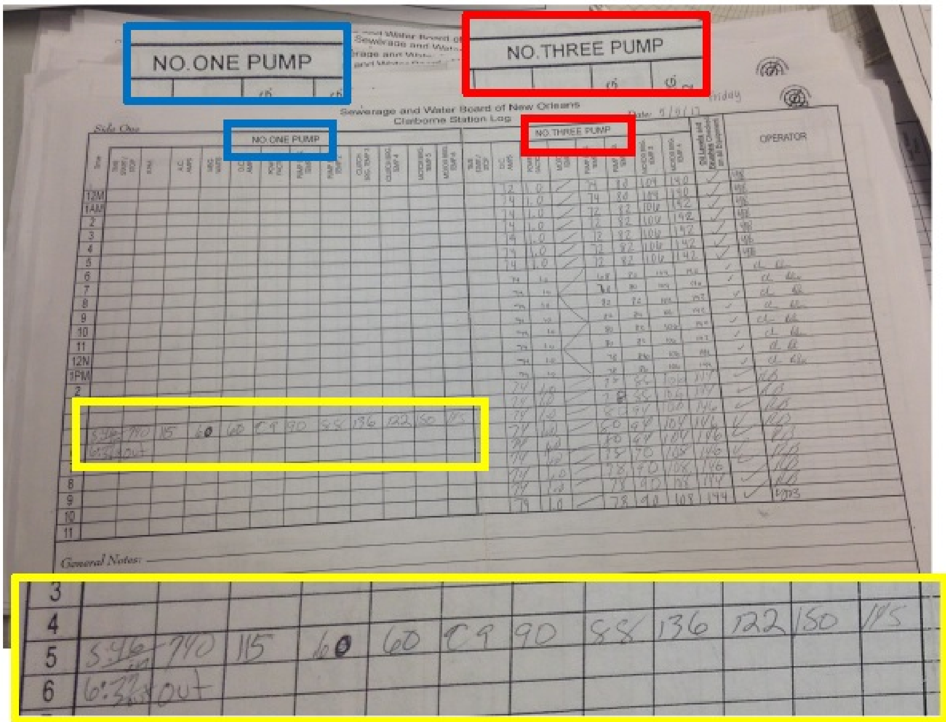
Entry reads: "Alarm in building went off at 5:40 PM and pressure dropped below 40 psi. Notified HIgh Lift and I was told to put #1 pump in at 5:45 PM. #1 pump in at 5:46 PM."

May 5, 2017 (3 PM -11 PM shift) entry in Claiborne Station written logbook

The response to the pressure drop was also captured on the Claiborne Station written data logs. Like the High Lift pump A & B written data logs, the Claiborne Station logs are also two sided. Pumps 2 and 4 are on one side, while pumps 1 and 3 are on the other:

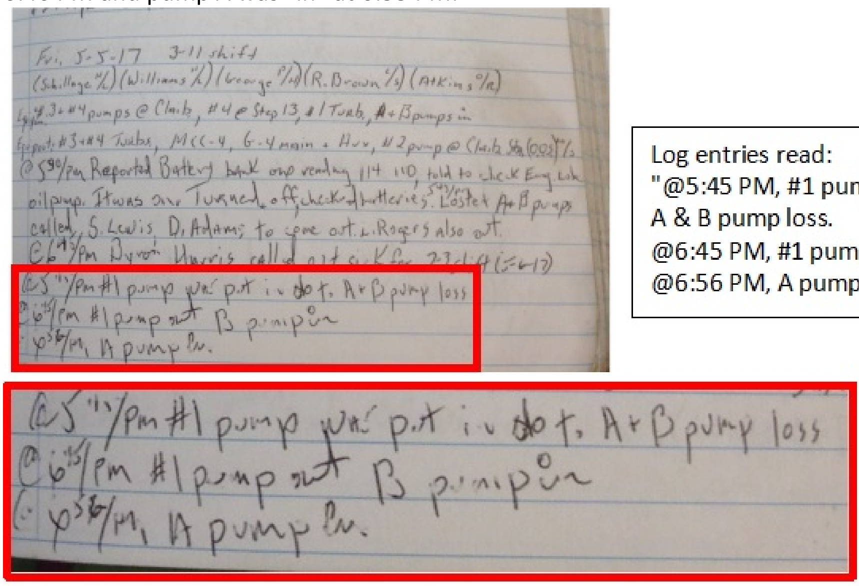


May 5, 2017 Claiborne Station log for pumps 2 and 4, showing pump 4 "in" and pump 2 idle



May 5, 2017 Claiborne Station log for pumps 1 and 3, showing pump 3 "in" the entire day and pump 1 "in" from 5:46 PM to 6:37 PM

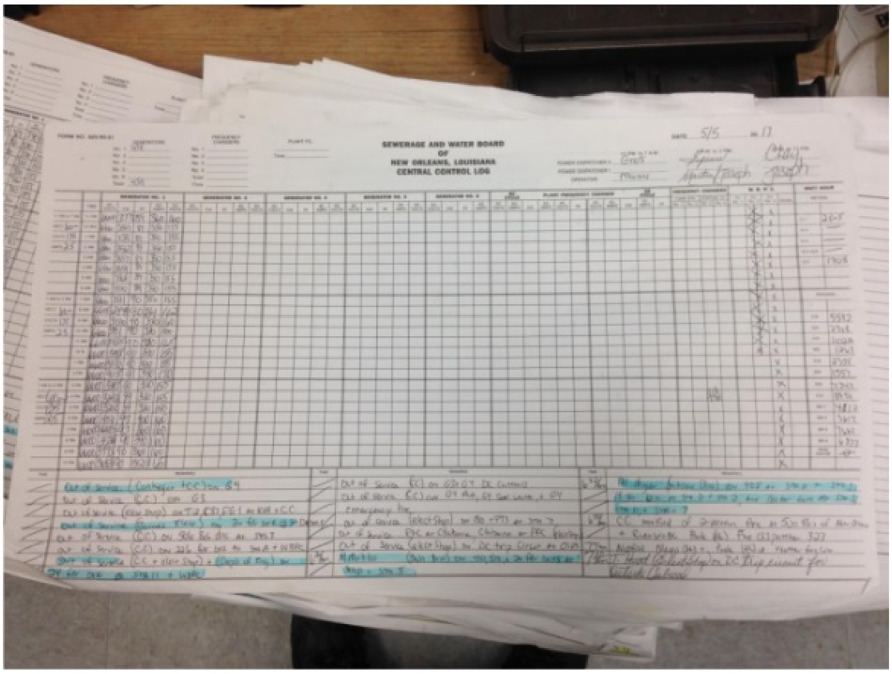
Putting Claiborne pump #1 "in" raised city water pressure to approximately 51 psi as measured at High Lift. Normal city water pressure of approximately 66 psi was restored about an hour later when A and B pumps were put back "in." According to the High Lift written logbook, pump B was "in" at 6:46 PM and pump A was "in" at 6:53 PM:



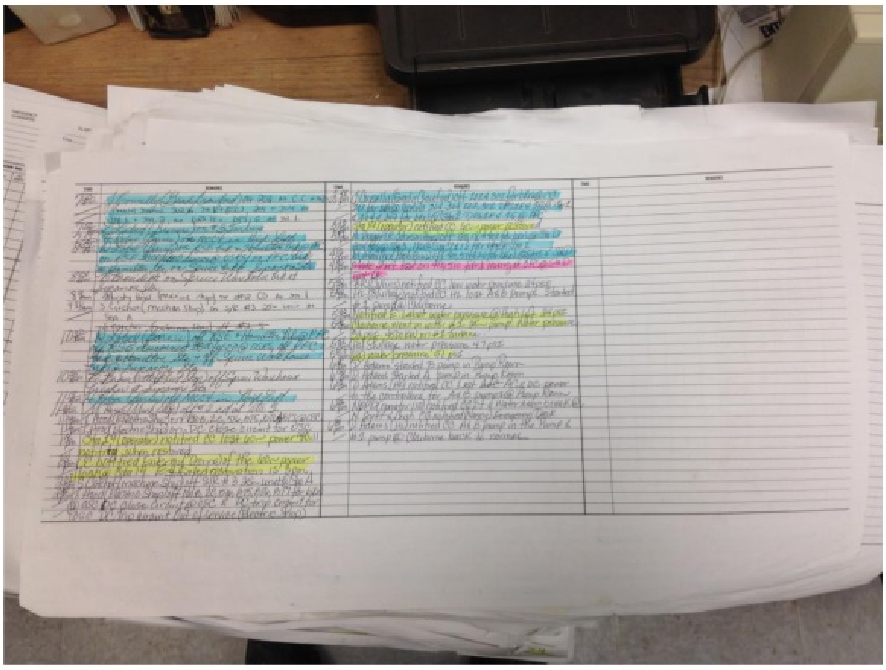
Log entries read:
"@5:45 PM, #1 pump was put in do to A & B pump loss.
@6:45 PM, #1 pump out, B pump in
@6:56 PM, A pump in"

May 5, 2017 (3 PM - 11 PM shift) entry in High Lift written logbook

Central Control noted these events in their log, with slightly different times:

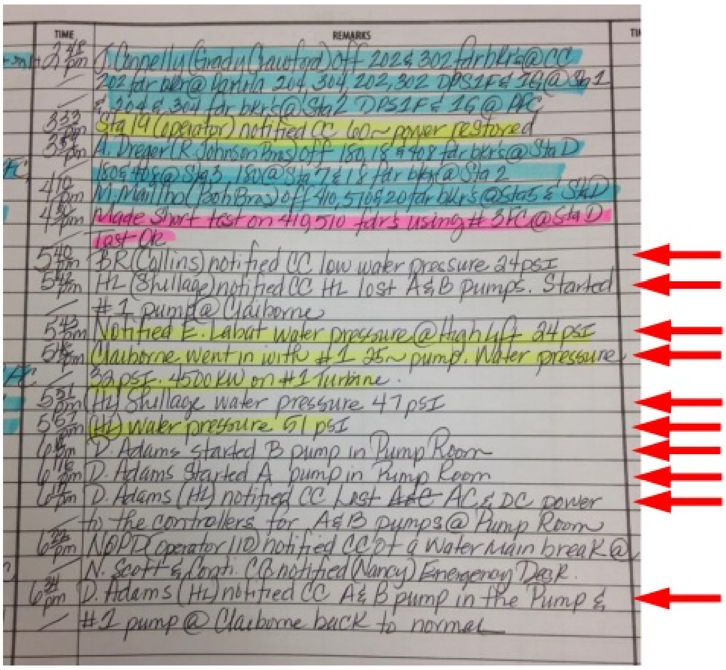


Front of May 5, 2017 Central Control log



Rear of May 5, 2017 Central Control log

Below is an enlargement of the relevant section of the Central Control log:



TIME	REMARKS
2:35 pm	J. Connelly (Grady/Crawford) off 202 & 302 fdr bkrs @ CC
	202 fdr bkr @ Carrollton 204, 304, 202, 302 DPS1F & 1G @ Sta 1
	204 & 304 fdr bkrs @ Sta 2 DPS1F & 1G @ PRC
3:33 pm	Sta 14 (operator) notified CC 60~ power restored
3:35 pm	A. Dreger (R. Johnson Bros) off 180, 18 & 408 fdr bkrs @ Sta D
	180 & 408 @ Sta 3, 180 @ Sta 7 & 18 fdr bkr @ Sta 2
4:10 pm	M. Manthos (Both Bros) off 410, 510 & 20 fdr bkrs @ Sta 5 & Sta D
4:30 pm	Made Short test on 410, 510 fdrs using #3 FC @ Sta D
	Test OK
5:40 pm	BR (Collins) notified CC low water pressure 24 psi
5:42 pm	HL (Shellage) notified CC HL lost A & B pumps. Started
	#1 pump @ Claiborne
5:43 pm	Notified E. Labat water pressure @ High Lift 24 psi
5:48 pm	Claiborne went in with #1 25~ pump. Water pressure
	32 psi. 4500 kW on #1 Turbine.
5:51 pm	(HL) Shellage water pressure 47 psi
5:57 pm	(HL) water pressure 51 psi
6:11 pm	D. Adams started B pump in Pump Room
6:16 pm	D. Adams Started A pump in Pump Room
6:17 pm	D. Adams (HL) notified CC Lost ~~A&B~~ AC & DC power
	to the controllers for A & B pumps @ Pump Room
6:26 pm	NOPD (operator 110) notified CC of a Water Main break @
	N. Scott & Canal. CC notified (Nancy) Emergency Desk.
6:34 pm	D. Adams (HL) notified CC A & B pump in the Pump &
	#1 pump @ Claiborne back to normal

Excerpt of rear of May 5, 2017 Central Control log, with water pump entries highlighted

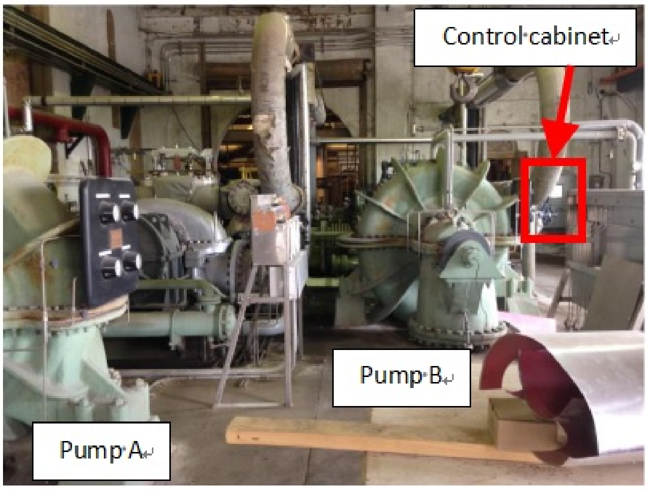
For clarity, the relevant entries are duplicated here, with abbreviations expanded into full descriptions:

5:40 PM: Boiler Room (operator Collins) notified Central Control of low water pressure: 24 psi
5:42 PM: High Lift (operator Shellage) notified Central Control [that] High Lift lost A and B pumps. Started #1 pump at Claiborne.
5:43 PM: Central Control notified Eric Labat the water pressure at High Lift is 24 psi.
5:48 PM: Claiborne went in with #1 (25 Hz) pump. Water pressure is 32 psi, 4500 kW [load] on #1 turbine.
5:51 PM: High Lift (operator Shellage) reports water pressure is 47 psi.
5:57 PM: High Lift reports water pressure is 51 psi.
6:11 PM: Damon Adams started B pump in pump room.
6:16 PM: Damon Adams started A pump in pump room
6:17 PM: Damon Adams notified Central Control [that High Lift] lost AC and DC power to the controllers for A & B pumps.
6:34 PM: Damon Adams notified Central Control A&B pump[s] and #1 pump at Claiborne back to normal.

Based on these logs and many others, it appears east bank city water pressure remained at its lowest levels for approximately 8 to 10 minutes.

<u>Failure of pumps A and B explained</u>

The cabinet housing the Woodward model 505 turbine controllers for pumps A & B and their common human-machine interface (HMI) is located in the A & B pump room:



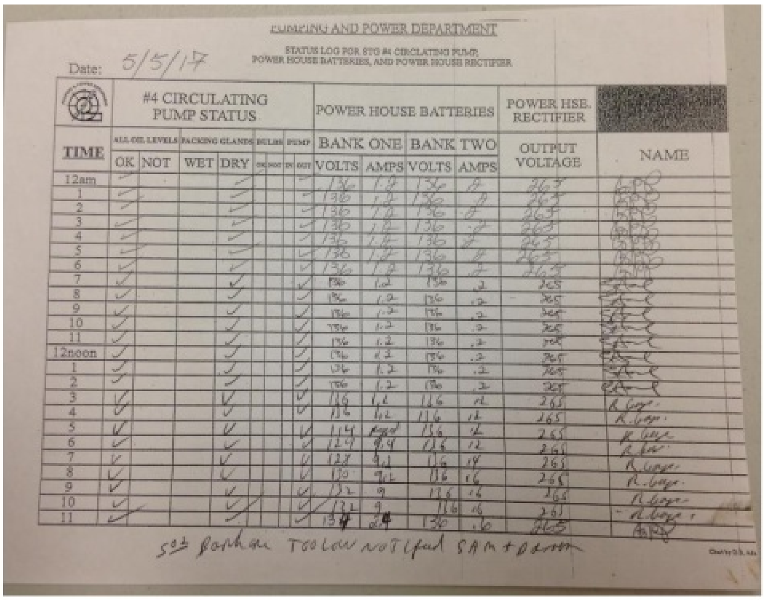
Pump A & B room at powerhouse

Control cabinet for pumps A and B

According to interviews with senior powerhouse staff, the cabinet is powered off a 60 cycle alternating current feed with backup direct current power off the powerhouse batteries. Unbeknownst to staff, at some point prior to May 5, 2017 one of those power sources had failed. According to staff, the panel never alarmed on this condition because of a programming error. When the second power source to the cabinet failed, it took down everything controlled by the cabinet: both pumps A and B. This is what the 6:17 PM note in the Central Control logs was referring to:

"6:17 PM: Damon Adams notified Central Control [that High Lift] lost AC and DC power to the controllers for A & B pumps."

The battery logs for the powerhouse show a drop in voltage and a spike in current at 5:02 PM on May 5, 2017, just prior to the loss of power to the controller:


PUMPING AND POWER DEPARTMENT

STATUS LOG FOR STG #4 CIRCULATING PUMP, POWER HOUSE BATTERIES, AND POWER HOUSE RECTIFIER

Date: 5/5/17

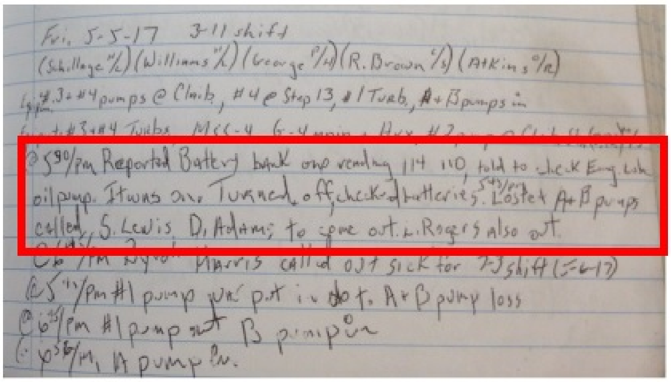
TIME	#4 Circulating Pump Status: All oil levels OK	All oil levels NOT	Packing glands WET	Packing glands DRY	Bulbs OK	Bulbs NOT	Pump IN	Pump OUT	Power House Batteries: Bank One VOLTS	Bank One AMPS	Bank Two VOLTS	Bank Two AMPS	Power Hse. Rectifier: Output Voltage	[redacted] NAME
12am	✓			✓				✓	136	1.2	136	.2	265	[illegible]
1	✓			✓				✓	136	1.2	136	.2	265	[illegible]
2	✓			✓				✓	136	1.2	136	.2	265	[illegible]
3	✓			✓				✓	136	1.2	136	.2	265	[illegible]
4	✓			✓				✓	136	1.2	136	.2	265	[illegible]
5	✓			✓				✓	136	1.2	136	.2	265	[illegible]
6	✓			✓				✓	136	1.2	136	.2	265	[illegible]
7	✓			✓				✓	136	1.2	136	.2	265	[illegible]
8	✓			✓				✓	136	1.2	136	.2	265	[illegible]
9	✓			✓				✓	136	1.2	136	.2	265	[illegible]
10	✓			✓				✓	136	1.2	136	.2	265	[illegible]
11	✓			✓				✓	136	1.2	136	.2	265	[illegible]
12noon	✓			✓				✓	136	1.2	136	.2	265	[illegible]
1	✓			✓				✓	136	1.2	136	.2	265	[illegible]
2	✓			✓				✓	136	1.2	136	.2	265	[illegible]
3	✓			✓				✓	136	1.2	136	.2	265	R. Gage
4	✓			✓				✓	136	1.2	136	.2	265	R. Gage
5	✓			✓				✓	114	pegged	136	.2	265	R. Gage
6	✓			✓				✓	124	9.4	136	.2	265	R. Gage
7	✓			✓				✓	128	9.1	136	[illegible]	265	R. Gage
8	✓			✓				✓	130	9.2	136	[illegible]	265	R. Gage
9	✓			✓				✓	132	9	136	[illegible]	265	R. Gage
10	✓			✓				✓	132	9	136	[illegible]	265	R. Gage
11	✓			✓				✓	134	[illegible]	136	.6	265	[illegible]

5:02 Bank one Too Low notified SAM + DAMON

Powerhouse battery log for May 5, 2017

The voltage on battery bank one dropped from its normal 136 volts at 4 PM to 114 volts at 5 PM and then rose back to normal through the evening. Current at 4 PM is shown as a normal 1.2 amps, but at 5 PM is shown as "pegged" and is a substantially elevated 9 amps the rest of the evening. A note at the bottom of the log with a 5:02 PM timestamp says, "Bank one too low, notified Sam and Damon." Sam and Damon are Sam Lewis and Damon Adams, senior supervisory personnel in the powerhouse. In reviewing all of 2017's battery logs, this was the only substantial note on any of them. In the absence of proper alarms, this sudden drain on the powerhouse batteries was likely the first indication of trouble on pumps A & B.

The few minutes later, the dwindling battery voltage was noted again in the High Lift written logbook:


Fri. 5-5-17 3-11 shift

#3+#4 pumps @ Climb, #4 @ Step 13, #1 Turb, A+B pumps in

@ 5:30/pm Reported Battery bank one reading 114 110, told to check Emg. Lub oil pump. It was on, Turned off, checked batteries. 5:45/pm Lost A+B pumps called, S. Lewis, D. Adams; to come out. L. Rogers also out.

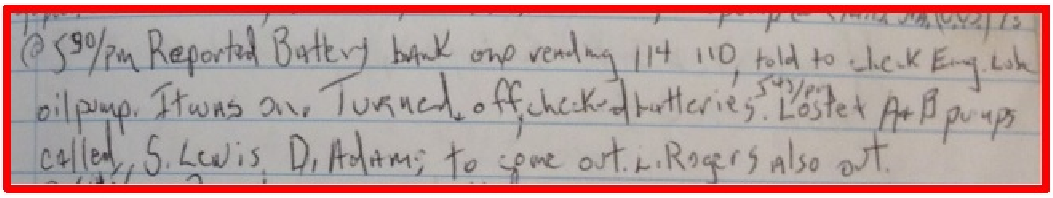
Harris called out sick for 7-3 shift (5-6-17)

A+B pump loss

B pump on

A pump on.

Log entries read:
"@ 5:30 PM Reported battery bank one reading 114, 110, told to check Emerg. Lube oil pump. It was on. Turned off, checked batteries.
"5:45 PM lost A & B pumps. Called [Sam] Lewis, [Damon] Adams to come out. [Lee] Rogers also out."


@ 5:30/pm Reported Battery bank one reading 114 110, told to check Emg. Lub oil pump. It was on, Turned off, checked batteries. 5:45/pm Lost A+B pumps called, S. Lewis, D. Adams; to come out. L. Rogers also out.

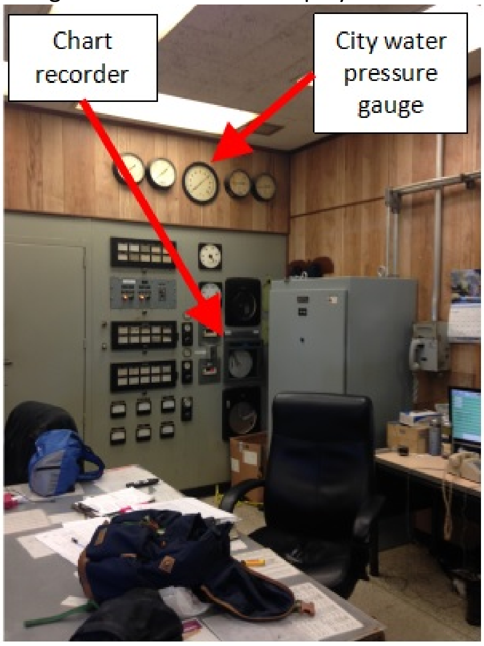
May 5, 2017 (3 PM - 11 PM shift) entry in High Lift written logbook

According to senior powerhouse staff, the power supply programming error was discovered later and rectified; power losses to the control panel now alarm properly. However, the alarm signal is still confined to the local control panel in the pump room. There is no connectivity between the pump

room and the High Lift control room. In addition, electronic instrumentation to allow for online monitoring of the turbines and pumps in the pump room has only been installed on one of the pumps. According to staff, full instrumentation packages and connectivity outside the pump room are part of the boiler room enhancement project, which - as of August 10 - was scheduled to go out for bid this month.

Monitoring of low water pressure

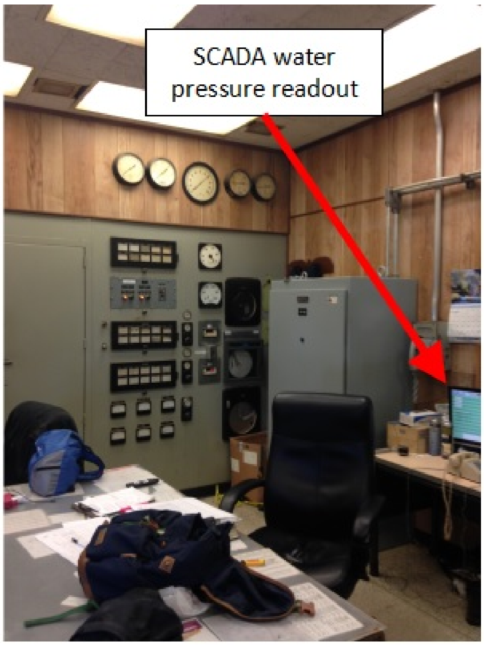
At the center of any low water pressure incident is the High Lift operator and the equipment in the High Lift control room. Water pressure in the control room is monitored in multiple ways. A large manual gauge on the wall gives instantaneous city water pressure. The chart recorder below the gauge - in addition to providing an historical record for 24 hours - also includes an instantaneous scrolling readout on an LED display above the chart:

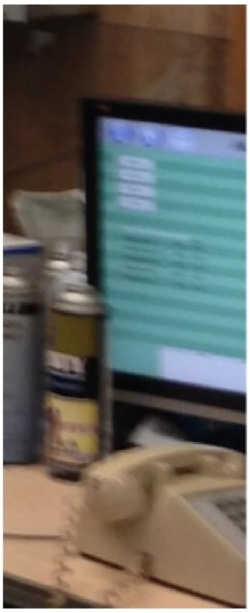


High lift control room in S&WB powerhouse

Chart recorder:
City water press. (blue), steam press. (red)

Finally, a collection of local city water pressure readings from ABB model SM3000 Supervisory Control and Data Acquisition (SCADA) system data recorders installed at Board facilities - gathered via Modbus on to a single display - also includes a value for city water pressure:

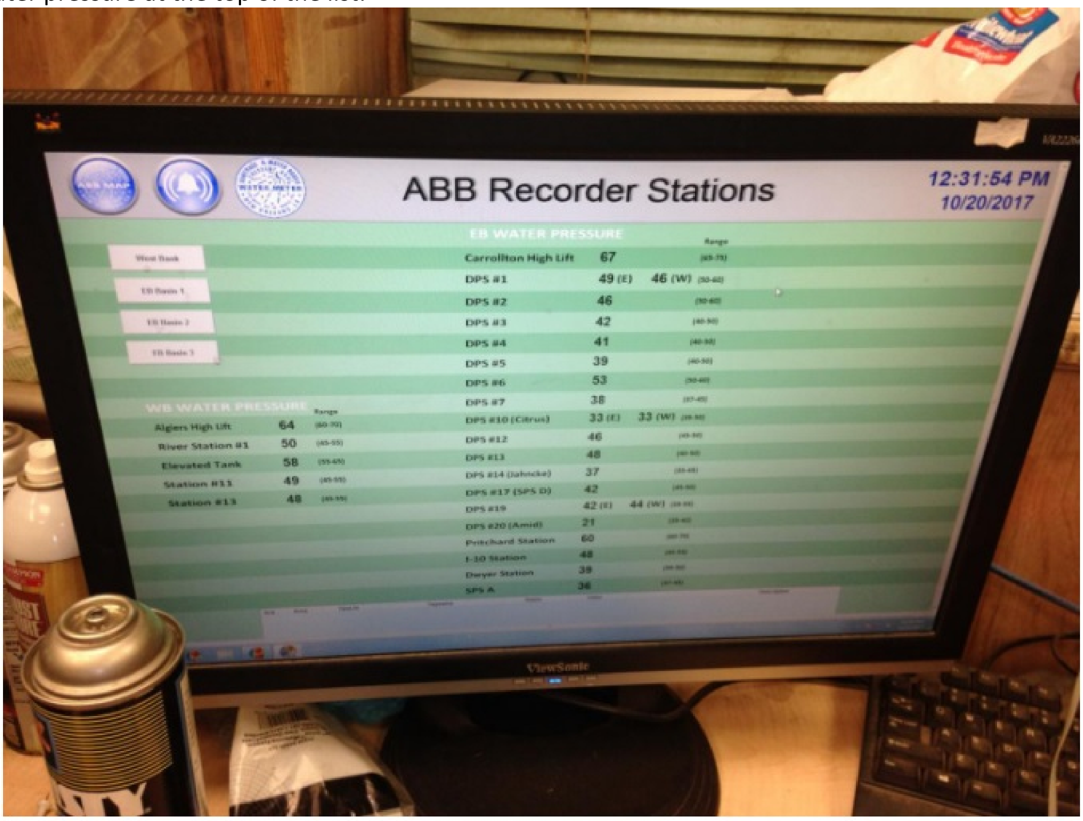




High lift control room in S&WB powerhouse

Monitor displaying city water pressure readings across the city at S&WB facilities

Here is a clearer picture of the High Lift SCADA water pressure display, with "Carrollton High Lift" water pressure at the top of the list:

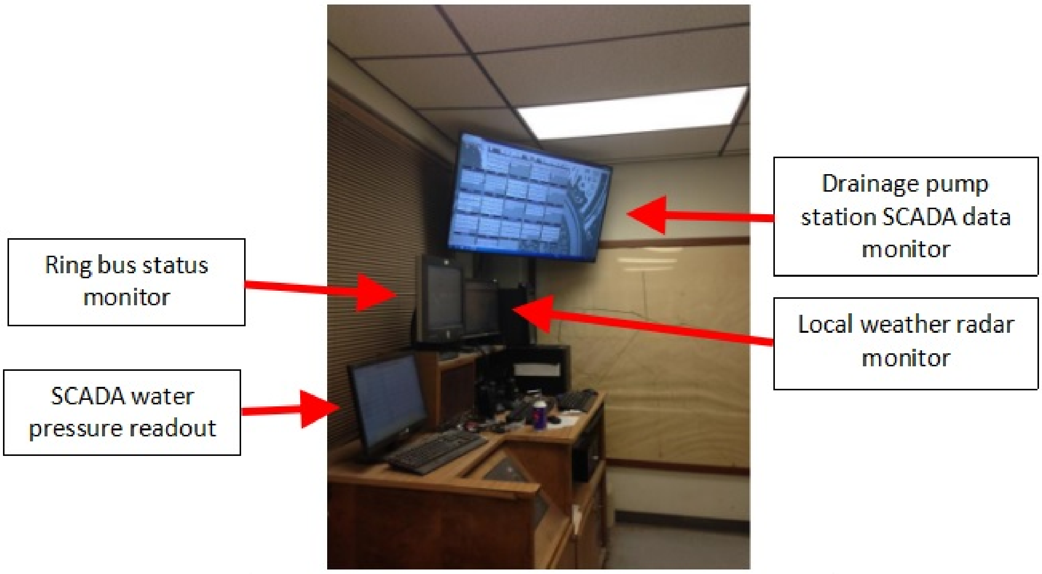


High Lift SCADA display of water pressures throughout the system, including High Lift.

The High Lift operator relies on the manual gauge rather than the SCADA data. One reason given is a loss of 60 cycle power to High Lift - as can occur during a power surge or loss of turbine 6 when in use

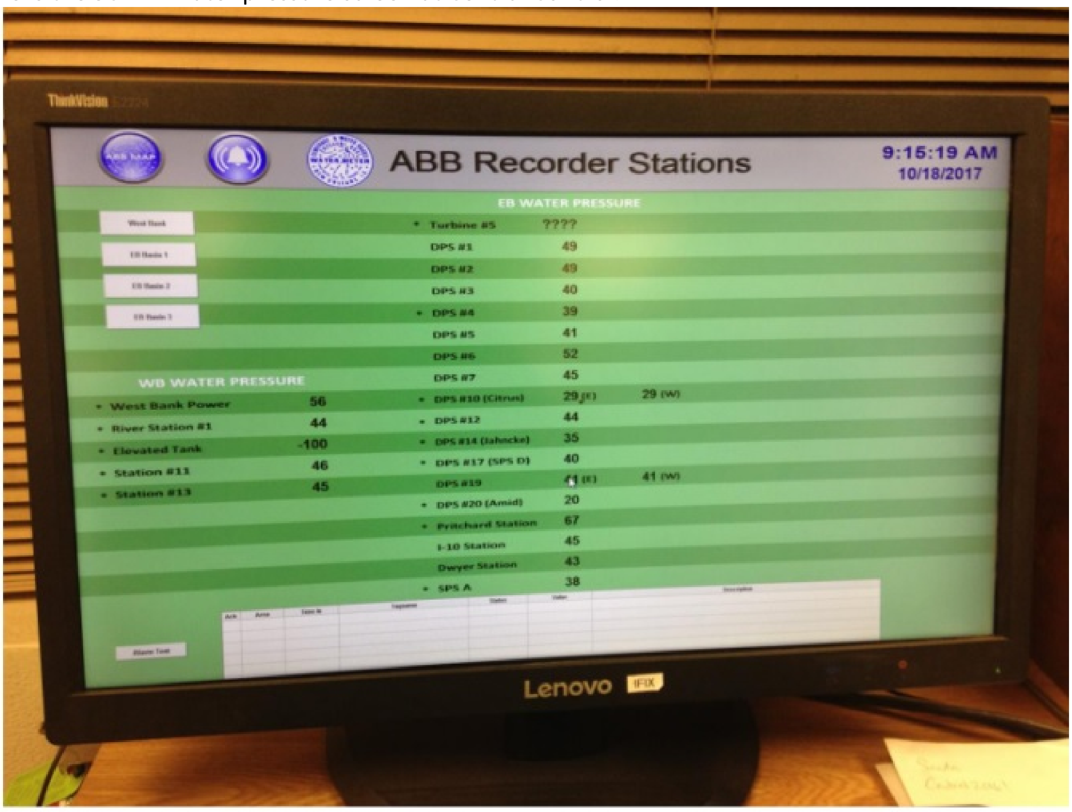
- will disable the SCADA monitor. These occasions are rare, and most times the SCADA data is available.

Central Control also hosts a water pressure SCADA monitor among a suite of condition monitors:



Condition monitors at Central Control

Here is the SCADA water pressure screen at Central Control:



Central Control SCADA water pressure monitor screen

Note the screens at High Lift and Central Control are not identical. The most prominent difference is the top level number at High Lift is labeled "Carrollton High Lift," while at Central Control it is labeled "Turbine #5." It is unclear if these represent the same number. Also noteworthy in the photo above

of Central Control's screen are the question marks next to the "Turbine #5" label. This indicates a loss of power to the instrument measuring water pressure at that location. This was explained by work proceeding on turbine #5 the day the photo was taken. Other differences are noted elsewhere in this report.

<u>Alarms and notifications for low water pressure</u>

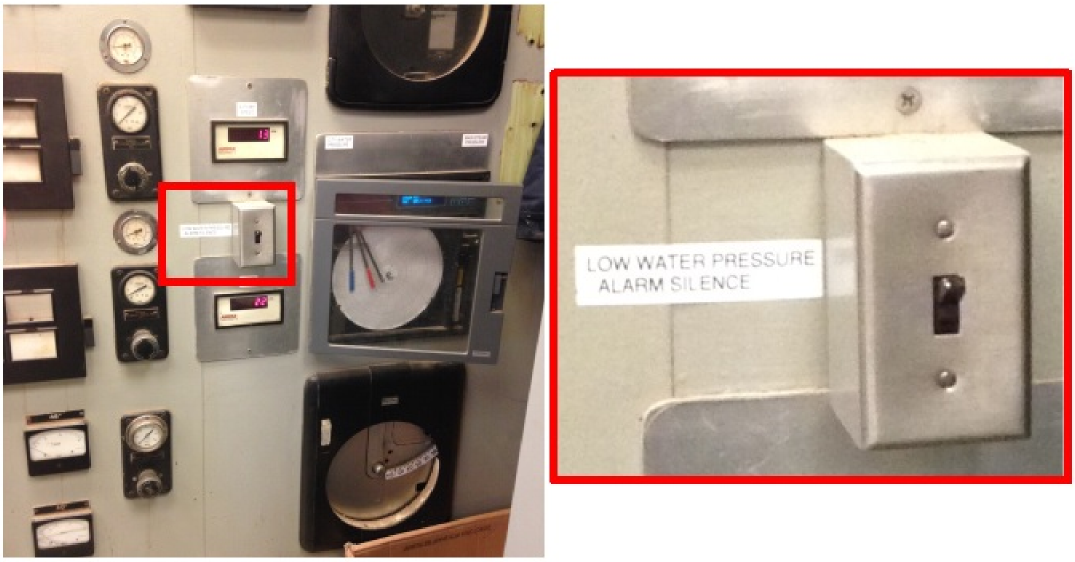
The alarm limit for low water pressure at both High Lift and Claiborne Station is 65 psi. Below that pressure, audible alarms are triggered in the High Lift control room and within Claiborne Station. The High Lift operator reports the alarm is quite loud and cannot be ignored within the control room.

There is no obvious speaker on the High Lift control room wall from which the alarm eminates, so it must be within the instrument cabinet:

High lift control room in SWB powerhouse: low water pressure alarm sounds from wall with gauges

Powerhouse staff and operators report there are no visible strobes or lights throughout the powerhouse to indicate a low water pressure condition. In addition, the audible low water pressure alarm can only be heard in the High Lift control room. Note that every hour, the High Lift operator is out of the control room to perform rounds, which can take between 15 and 30 minutes. Outside of the hours of 7 AM and 3 PM, when a trainee helper might be in the room, it is possible the High Lift control room could be unoccupied for 15 to 30 minutes of every hour.

Installed just to the left of the city water pressure chart recorder is a two position switch which can silence the low city water pressure alarm.

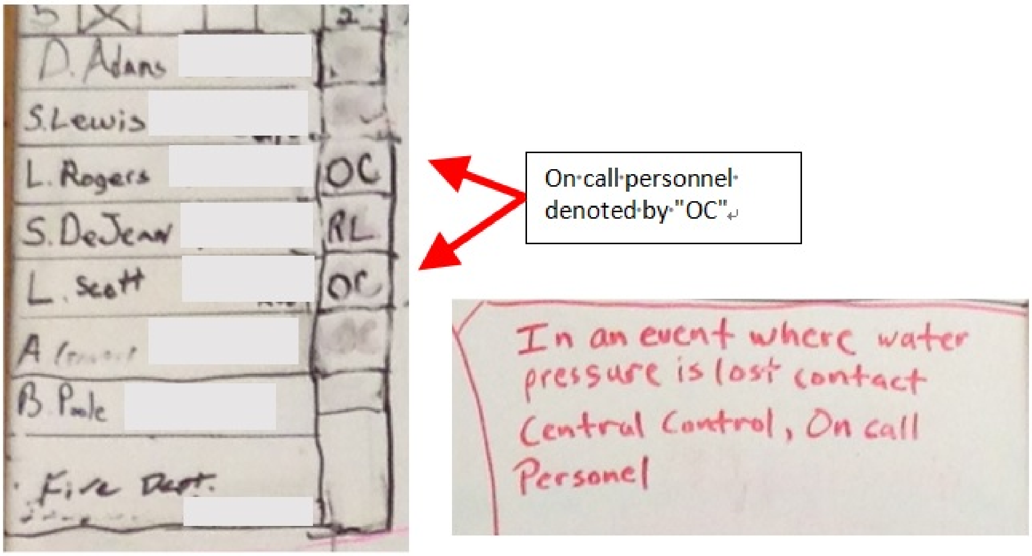


High Lift control room in SWB powerhouse: low water pressure alarm silence switch highlighted

This switch does not resolve the alarm condition, it only turns the noise of the alarm off. The switch is of a design identical to a household light switch: once the alarm silence is activated, it can remain in that condition until turned off. There does not appear to be any timer or other control to dismiss the silence after a time or resolution of the alarm condition.

In Central Control and at High Lift, alarms have been programmed for each of the Board facilities shown on the SCADA monitor screen. Visibly, an alarm appears in the log window at the bottom of the screen. At Central Control an audible alarm sounds, but at High Lift operators report no audible alarms from their SCADA display. It is unknown if High Lift's lack of an audible alarm is due to a problem with the setup of the computer or if the programming at this terminal keeps the alarms silent.

As to notification of personnel beyond High Lift during a low water pressure event, the system is a mix of low tech phone calls and some electronics. Since the High Lift operator's time is best spent on responding to such an event, notifications by the operator are kept to a minimum. The whiteboard in the High Lift control room includes information for the High Lift operator, indicating just On Call personnel and Central Control should be contacted:



Details from whiteboard in High Lift control room, October 13, 2017

Once notified by the High Lift operator, the On Call personnel or Central Control then notify more senior personnel, likely by phone.

As to who else is made aware of low water pressure alarms at the time they activate, it appears the Boiler Room control room has access. On May 5, Central Control's log notes that the Boiler Room was the first party to alert them to the low water pressure:

"5:40 PM: Boiler Room (operator Collins) notified Central Control of low water pressure: 24 psi"

I have been told SCADA monitors similar to those in Central Control and High Lift were placed in the offices of senior Sewerage & Water Board leadership such as the Operations Chief and the General Superintendent. It seems likely these monitors also include alarms in their programming. In addition, I have also been told low water pressure alarms are programmed to push emails to a select group of Sewerage & Water Board senior staff and leadership.

The Central Control operational logs make mention of these alarms activating at other times in 2017 when low water pressure was registered at drainage pump stations as a result of local water system networks repairs. In those cases, senior leadership such as the General Superintendent or the Operations Chief are noted as reporting back to Central Control quickly with causes for the alarms, indicating they were routinely in the loop for such occurrences. Here are two such examples:

June 8, 11:10 AM, "[Central Control] received low water pressure alarm for sta 4, notified station operator and Ashley (emergency) central yard dispatch"
June 8, 12:45 PM, "[Operations Chief Vincent] Fouchi [notified Central Control] low water pressure at sta 4 was due to water closure near sta 4. No SWB dep't was notified."

July 5, 9:18 AM, "Received SCADA [alarm] for low water pressure at I-10 (14 psi) and sta 12 (6 psi), notified J. Becker, emergency desk and C. James"
July 5, 9:23 AM "J. Becker [notified Central Control] that [there is a] contractor working outside sta 12 and that is what is affecting water pressure."

Interviews with powerhouse personnel indicate the email distribution list for such alarms does not include all key powerhouse personnel. Also, text alerts are apparently not generated through this system, only emails. Since not everyone sets their cellphone up to alert on new emails, such a system could result in delays in notification of key supervisory personnel.

City water pressure losses at the Carrollton Water Plant are felt throughout the city

Typical city water pressure as measured at High Lift, which is considered the official number, is between 66 and 72 psi. The alarm limits are between 65 and 75 psi. Notable about the pressures at remote locations seen in the photos of the SCADA displays above - which are typical - is how far below 66 to 72 psi most of them are. The closest drainage pumping station to the Carrollton Water Plant, Pritchard Station in Hollygrove, naturally suffers from the smallest pressure loss. Others, though, see between 15 and 30 pounds of pressure drop between the plant and the pump station.

This is critical because a large pressure loss at the water plant can cause similarly large pressure losses at stations around the city, stations which are already operating at a significant pressure deficit. Historically, if the pressure at one or more of these stations drops below the state-recommended 15 psi, a precautionary boil water advisory is usually triggered. The advisory is intended to guard against health effects of bacteria which could infiltrate the water supply when pressure grows too low, placing residents' health at risk. Especially vulnerable are infants, the elderly, and people with compromised immune systems.

A boil water advisory can be localized to one or more specific neighborhoods, or it can be citywide for either the east or west banks. The most recent localized boil water advisory was issued for the Venetian Isles area on June 22, 2017, while the most recent east bank boil water advisory was issued September 20, 2017. Before that, the last east bank boil water advisory was on September 23, 2015 and last local boil water advisory was for the Lower Ninth Ward on June 2, 2016.

To understand fully the city water pressures as reported at the drainage pumping stations, it is necessary to review some basic facts about the water pressure transmitters in the stations. These include SCADA labeling, transmitter manufacturers and models, and transmitter installations.

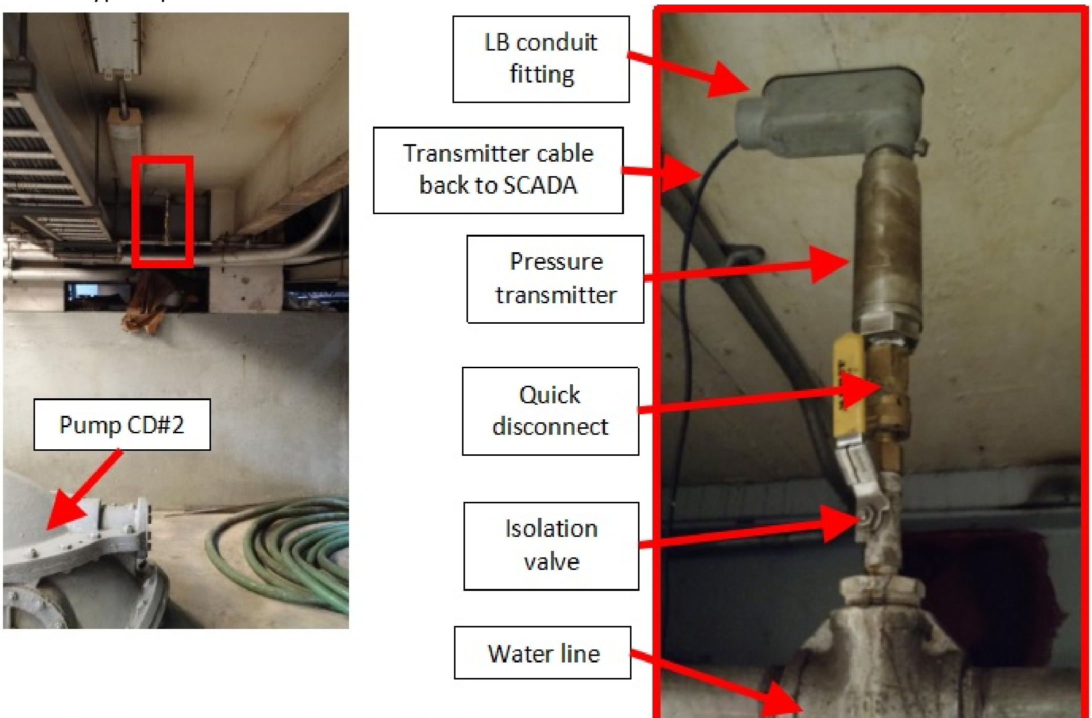
Pressure transmitter SCADA labeling
Almost all drainage pumping stations have two sources of city water. This redundancy allows for maintenance and operational flexibility. Unfortunately, labeling of these different sources in the stations' SCADA systems is not consistent, and not all sources are monitored with pressure transmitters. The following is a summary of city water SCADA pressure transmitter labels at selected drainage pumping stations considered within this report (this does not take into account whether the station has two sources of water, only which sources have pressure transmitters on them and the names given those transmitters):

Location	SCADA pressure source names
DPS 1 (Broadmoor)	25 Hz H2O 60 Hz H2O
DPS 2 (Mid-City)	System pressure
DPS 3 (Mid-City)	System pressure
DPS 4 (Gentilly)	Water pressure
DPS 5 (Lower Ninth Ward)	System pressure Water pressure
DPS 7 (City Park)	System pressure Water pressure
DPS "D" (Peoples Ave)	Water pressure
DPS I-10 (Cemeteries)	System pressure
DPS 10 (Little Woods)	East H2O West H2O
DPS 20 (GIWW/Jourdan Ave)	System pressure Water pressure

Pressure transmitter technical details
In stations surveyed to date, two models of pressure transmitters have been used: the Viatran model 570 with a 0-75 psi range and the GP:50 model 311X/P with a 0-100 psi range. Both are functionally

equivalent to each other and both appear to be adequate for the service. Manufacturer technical information indicates both models have an accuracy of +/- 0.5%.

Pressure transmitter installation details
Here is a typical pressure transmitter installation:



"25 Hz" pressure transmitter at DPS #1, located in basement on water line to constant duty pump #2

Most other installations include pressure gauges at the transmitter branch to allow for field verification of transmitted pressure values, but some are similar to the one above. In those cases, upstream or downstream pressure gauges - some of which are a great distance from the transmitter - must be relied upon to verify transmitter readings. Also, some other installations have the transmitter cable protected in flexible conduit, but others - like the one above - leave the cable unprotected. Finally, many transmitters are located as close as possible to the entry point of the water line into the station, so that the transmitted value represents city water pressure as closely possible. The one above is located downstream of a number of fittings of gradually decreasing diameter, approximately 100 to 150 linear feet from the water line penetration through the station's northeast wall, which is less than ideal.

According to the SCADA data, below are the lowest pressure readings recorded at a selection of drainage pumping stations around the city on the afternoon of May 5, 2017 during the time between pumps A and B going down and Claiborne pump 1 starting up and loading. Please note that the highlighted locations (those with lowest pressures below 15 psi) are the subject of lengthy discussion later in this report.

Location	Lowest pressure (psi)	Pressure before drop (psi)	Amount of drop (psi)
DPS #1 (Broadmoor) "60 Hz H2O"	**3.6***	28.7*	25.1
DPS #1 (Broadmoor) "25 Hz H2O"	**6.2***	31.0*	24.8
DPS #2 (Mid-City) "System pressure"	21.5	53.0	31.5
DPS #3 (Mid-City) "System pressure"	16.4	45.4	29.0
DPS #4 (Gentilly) "Water pressure"	15.7	44.8	29.1
DPS #5 (Lower Ninth) "Water pressure"	**14.9**	43.4	28.5
DPS #5 (Lower Ninth) "System pressure"	16.7	47.7	31.0
DPS #7 (City Park) "Water pressure"	**11.7***	39.0*	27.3
DPS #7 (City Park) "System pressure"	18.2	50.9	32.7
DPS "D" (Peoples Ave) "Water pressure"	18.4	46.5	28.1
DPS I-10 (Cemeteries) "System pressure"	19.5	52.5	33.0
DPS 10 (Little Woods) "East H2O"	**11.7**	38.7	27.0
DPS 10 (Little Woods) "West H2O"	**11.7**	38.7	27.0
DPS 20 (GIWW/Jourdan Rd) "Water pressure"	**10.8***	35.8*	25.0
DPS 20 (GIWW/Jourdan Rd) "System pressure"	18.5	48.3	29.8

*Data may not be reflective of local pressure near the station

All locations experienced pressure drops of very similar magnitudes: between 25 and 35 psi. This demonstrates the citywide scope of the event.

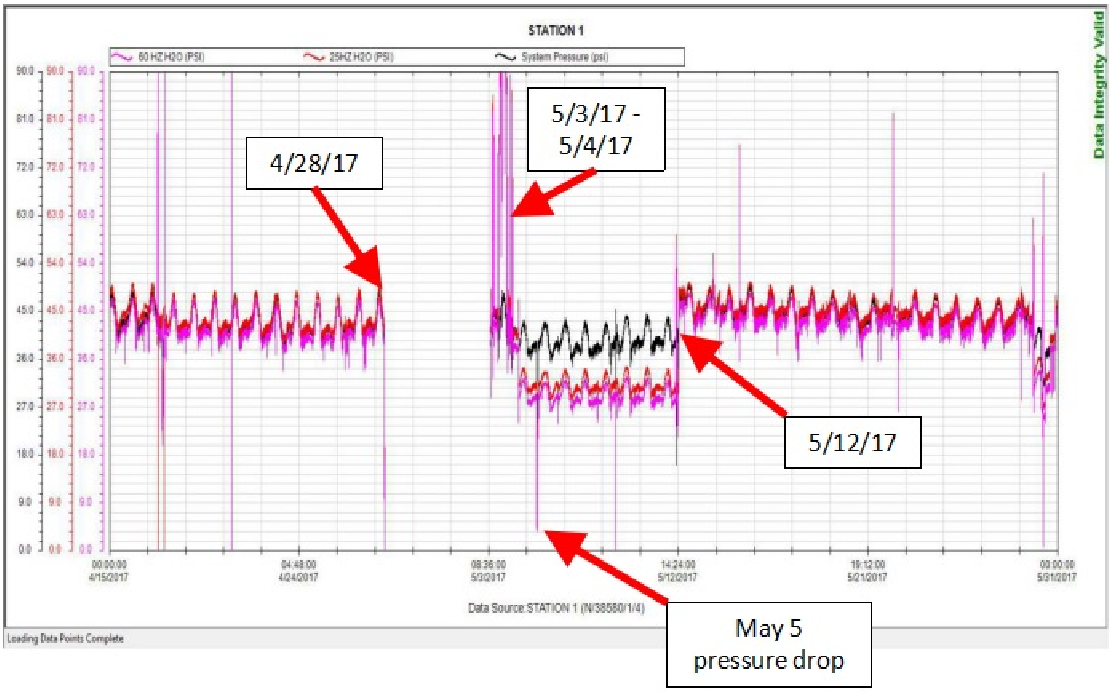
Two additional stations for which there are readable data - DPS 12 and DPS 19 - registered no loss (DPS 12) or a negligible loss (DPS 19). In the case of station 19, this could be because of booster pumps kicking on automatically to maintain station pressure. In the case of station 12, the data is at the very least misdated, and possibly unreliable. SCADA data for other stations was either not available or not usable before publication of this report. Please note there are other stations with SCADA data which could not be visited due to time restrictions. Also, all the underpass stations, DPS #12 and DPS Grant have their data collected by a separate SCADA system known by its brand name, Mission. The Mission data is available via password-protected website. Again, due to time restrictions Mission data was not reviewed.

<u>Details of five drainage pumping stations with city water pressures below 15 psi on May 5, 2017</u>

It is prudent to determine whether the water pressures below 15 psi recorded on May 5 can be trusted as representative of the water pressure in the surrounding neighborhoods. To reach such a determination, a discussion of water pressure measurement at the five stations with sub-15 psi readings follows.

DPS #1
There is reason not to trust the data generated at DPS #1 on May 5, 2017, but that may not matter.

If one looks at the days before and after May 5, there are discrepancies in the data:



DPS #1 water pressures from 4/15/17 to 5/31/17: 60 Hz (purple), 25 Hz (red), system (black)

The SCADA system at DPS #1 adds an additional layer of processing beyond simply recording the water pressure from both sources to the station. A third value, labeled "system pressure," is an average of the two source pressures, "25 Hz H2O" (water entering on the east end of the building) and "60 Hz H2O" (water entering toward the west end of the building). On the chart above, 60 Hz H2O is in purple while 25 Hz H2O is in red. System pressure is in black. Normally, since there is so little difference between the two source pressures, the black line for system pressure is obscured by the other two lines. This can be seen in the period before April 28 and after May 12. In between those dates, though, there were challenges.

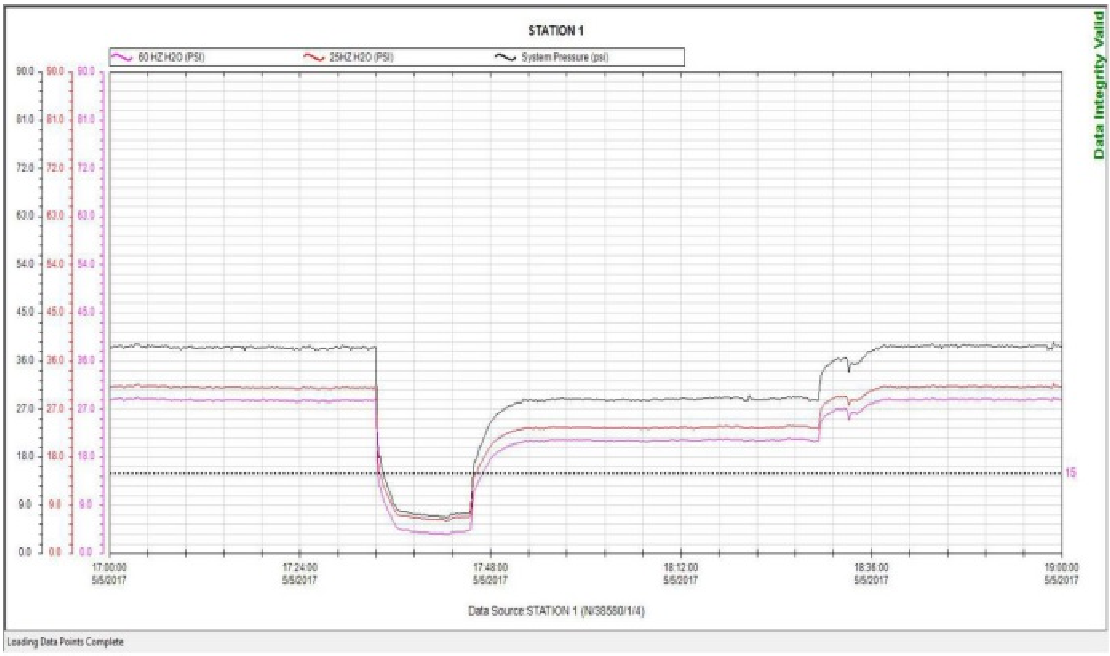
First, between April 28 and May 3 data archiving was offline. DPS #1 was not the only station struck by this problem. DPS #10 in New Orleans East experienced an identical loss of archiving of pressure transmitter data during the same timespan. The cause is unknown.

Second, on May 3 and May 4, the pressure data was extremely volatile. This volatility was observed in the SCADA systems at other stations such as DPS #5 during the same two day period. The cause is unknown at this time.

Finally, during the period from May 4 to May 12, "system pressure," which as an average should be between the other two pressures, instead registered significantly higher than both. Also, the values for 60 Hz H2O and 25 Hz H2O ran quite a bit lower than normal. Both these conditions argue against good quality data between May 4 and May 12.

Whatever the reasons for the garbling of the station 1 water pressure SCADA data between April 28 and May 12, it leads to the conclusion that the data during that period for all three water pressure parameters (25 Hz H2O, 60 Hz H2O, and system pressure) - which includes May 5 - is not trustworthy for purposes of this review.

But - and this is important - it is unclear if all this detail was known at the time to Sewerage & Water Board senior staff and decisionmakers. At the time of the May 5, 2017 water pressure loss, all three parameters fell significantly below 15 psi (represented by the dotted line across the chart):



DPS #1 water pressures from 5 PM to 7 PM on 5/5/17: 60 Hz (purple), 25 Hz (red), system (black)

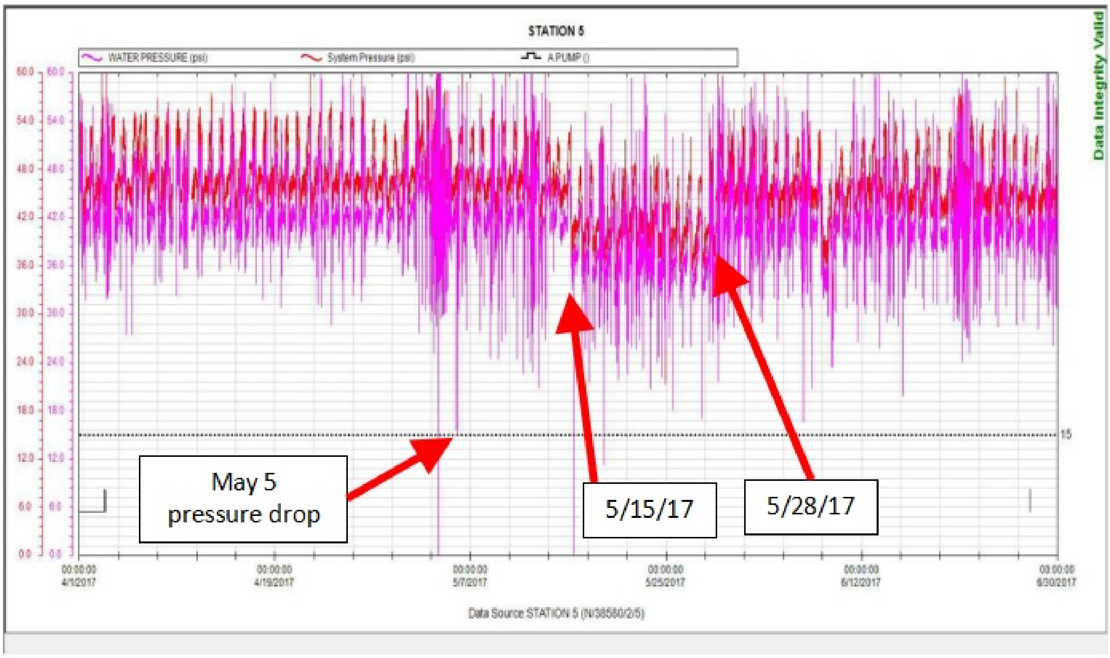
So while the data for May 5 for station 1 is probably not valid, the knowledge of and reaction to that data - invalid or not - are of interest and merit additional scrutiny. This is also a concern when considering low pressure readings at other stations, as discussed below.

DPS #5

At DPS #5 in the Lower Ninth Ward, there are two water inlets in the main building. Each has a pressure transmitter mounted on it. In the SCADA system, one transmitter is labeled "system pressure" and the other is labeled "water pressure." For 2017, "normal" performance of the two DPS #5 pressure transmitters includes the "system pressure" running a few psi higher than the "water pressure," and both values averaging in the low- to mid-40 psi range. The difference between the two pressures does not appear to be caused by leakage on one side of the system, as can be seen at DPS #7 or possibly at DPS #20 (see below). The difference is steady, even when there are no uses of flowing water at the station. Through April and June, SCADA pressure transmitter performance at DPS #5 appears to have been "normal." Problems with SCADA data in May - the month of the pressure drop incident - require closer examination to ensure the data for May 5 can be trusted.

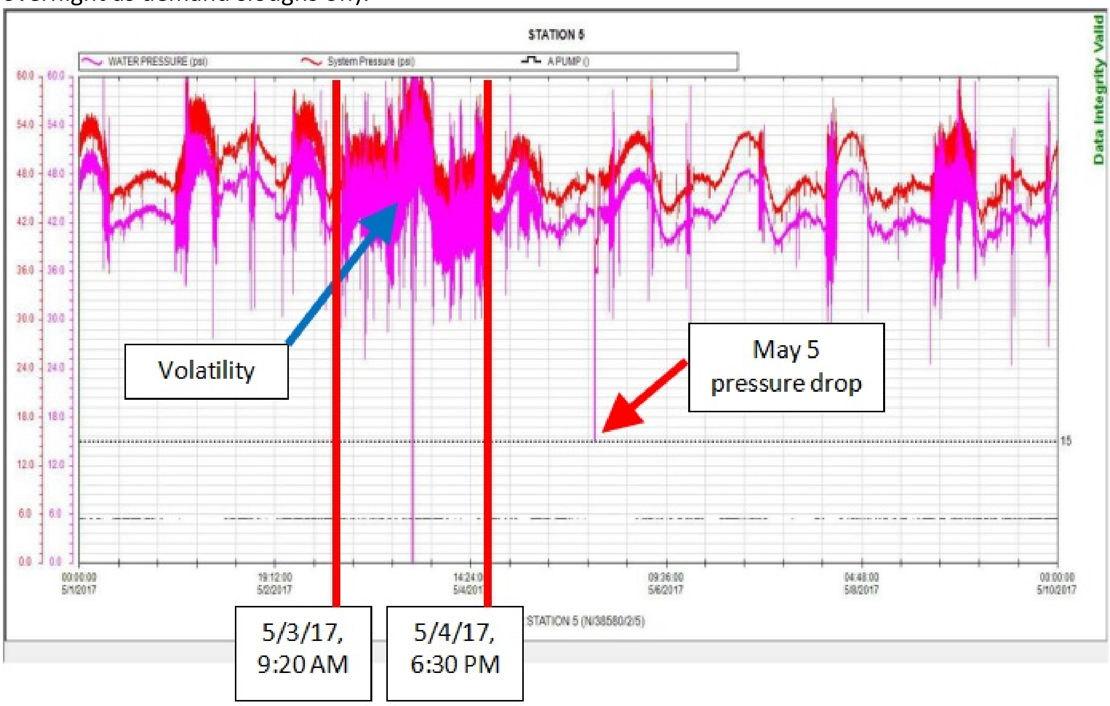
In May the system experienced two problems. Similar to DPS #1, the SCADA system recorded a great deal of volatility on May 3 and May 4. Also, DPS #5 SCADA system also appeared to suffer a days-long lowering of its water pressure data, with average pressures for both inlets dropping about 5 to 6 psi between May 15 and May 28. Both these problems have also been seen at other pump stations, indicating they are not localized to DPS #5.

Two charts below show this story. The first shows DPS #5's SCADA pressure data from April 1 to June 30. "Normal" service can be seen on this chart in April and June, as well as the falloff and recovery of pressures between May 15 and May 28:



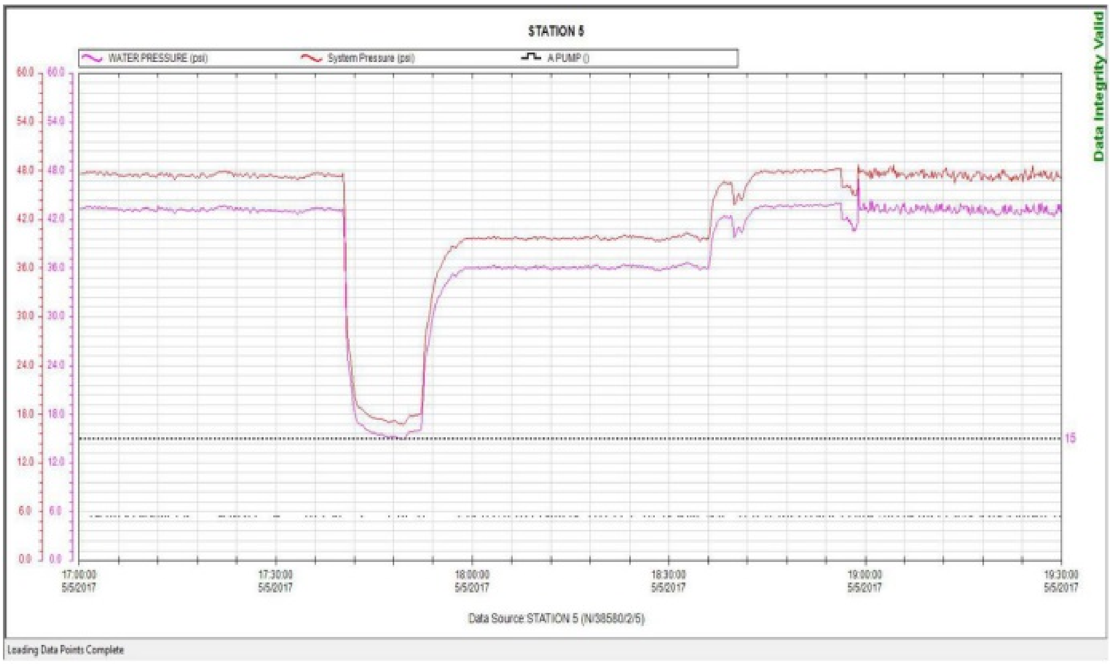
DPS #5 water pressure (purple) and system pressure (red) from 4/1/17 to 6/30/17

Zooming in to the beginning of May, one can see the volatility on May 3 and 4 clearly, and also how it had stopped by the time of the water pressure drop on May 5 (the daily up and down represents the normal rhythm of water pressure in the city, with a trough during the day's top demand and a peak overnight as demand sloughs off):



DPS #5 water pressure (purple) and system pressure (red) from 5/1/17 to 5/10/17

Based on these wider views of the data and the historic steadiness of both readings - as well as a check of pressures at 5 PM on Fridays throughout the months leading up to Friday, May 5 - the pressures leading into and out of the pressure drop on May 5 appear to be well within the "normal" band for operation of DPS #5:



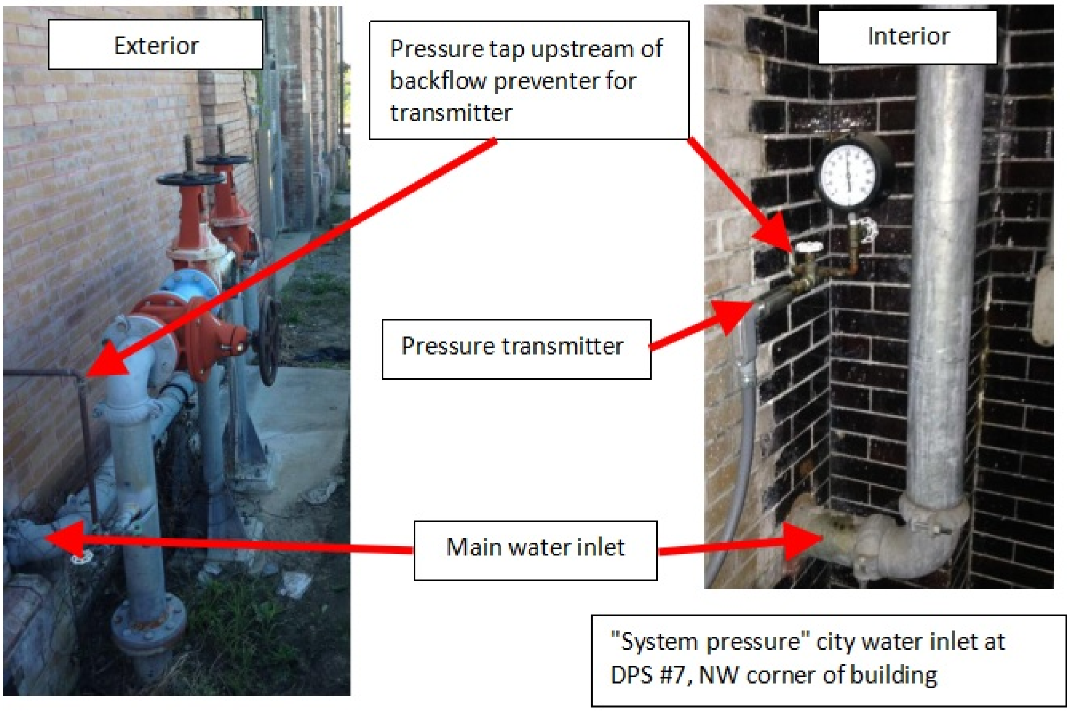
DPS #5 water pressure (purple) and system pressure (red) on May 5, 2017, 5:00 PM to 7:30 PM

As such, the data for May 5 at station 5, including the drop of city water pressure below 15 psi, appear to be valid and reflective of city water pressure outside the station.

Both pressure transmitters at DPS #5 are Viatran model 570's,with ranges of 0 to 75 psi. Using the manufacturer's linearity of +/- 0.5% and applying it to the full range of 75 psi, the error in pressure measurement is +/- 0.4 psi. Taking this into account, any pressure reading below 15.4 psi could actually indicate a pressure below 15 psi. According to the SCADA records, "water pressure" at DPS #5 dipped below 15.4 psi for 3 minutes and 10 seconds on May 5, 2017.

DPS #7

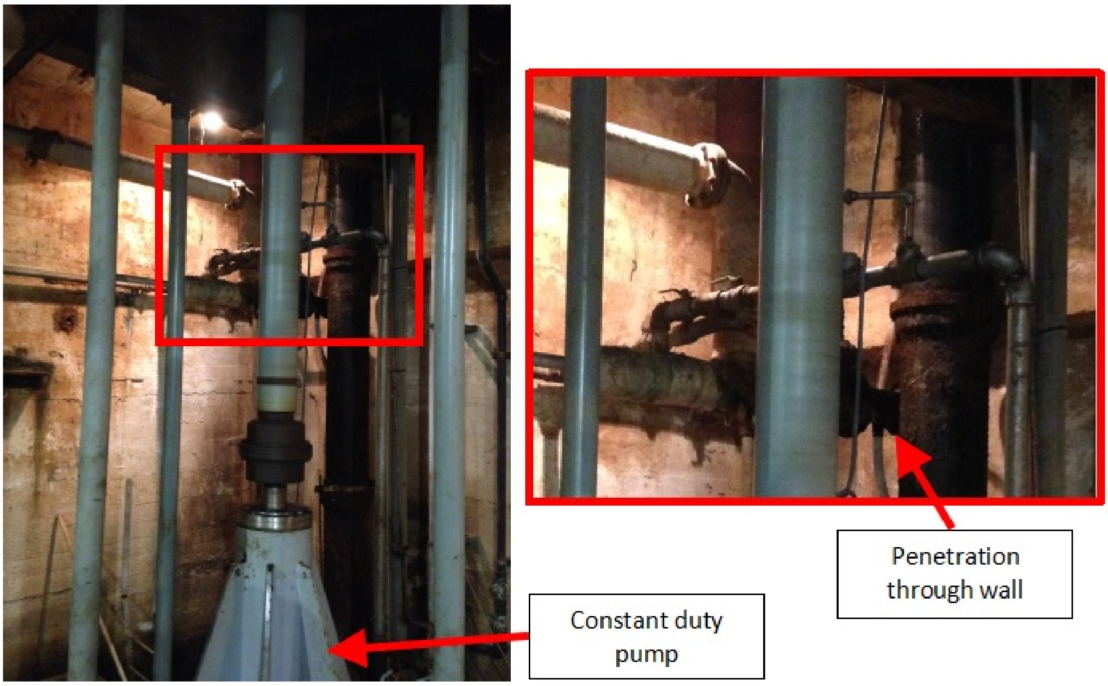
DPS #7 on Marconi Drive has two water inlets, both on the station's west side. One is at the northwest corner of the building. Its' pressure transmitter is labeled "system pressure" in the SCADA system. The transmitter is installed on a pressure tap upstream of all equipment, including the backflow preventer. As such it represents the best unimpeded measurement of local city water pressure:



"System pressure" city water inlet at DPS #7, NW corner of building

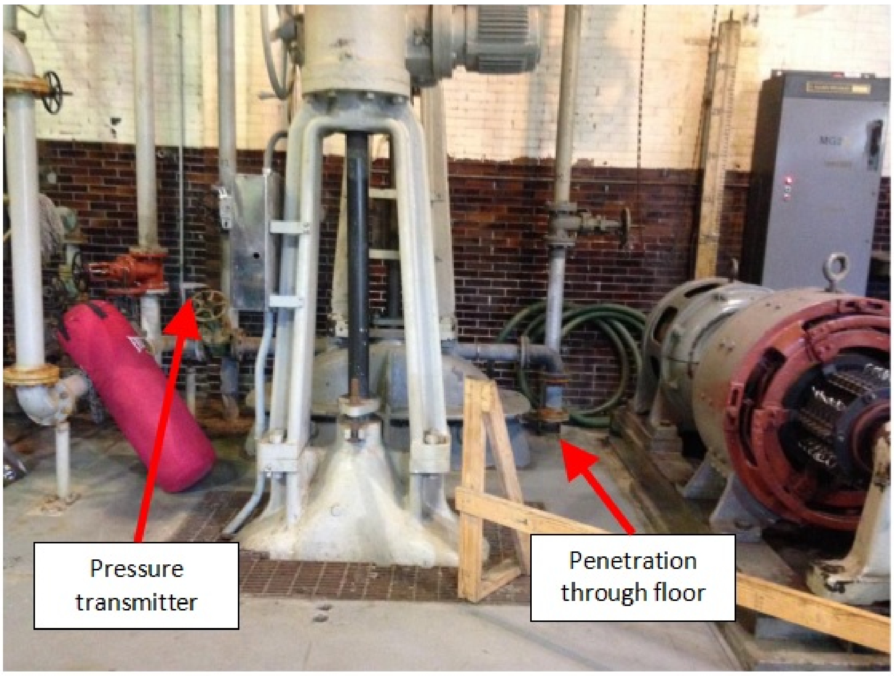
The other inlet also enters from the west side of the building. It flows through a backflow preventer mounted above the grating on the south side of the station and then proceeds to a tee. One line from the tee proceeds into the building in the constant duty pump pit, while the other line goes out to the Marconi underpass station.

"Water pressure" city water inlet at DPS #7: backflow preventer on south side of station



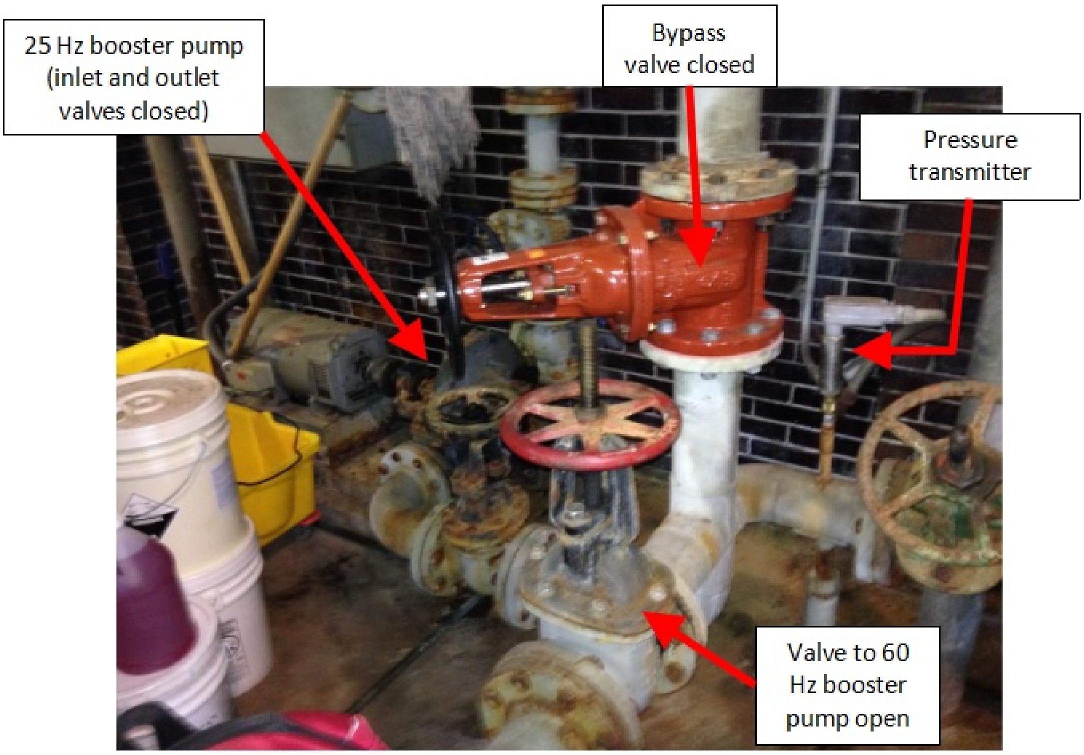
"Water pressure" city water inlet at DPS #7: penetration through south wall (view looking SE)

The pressure transmitter for this inlet is located adjacent to the station's booster pumps, at the north wall of the station:



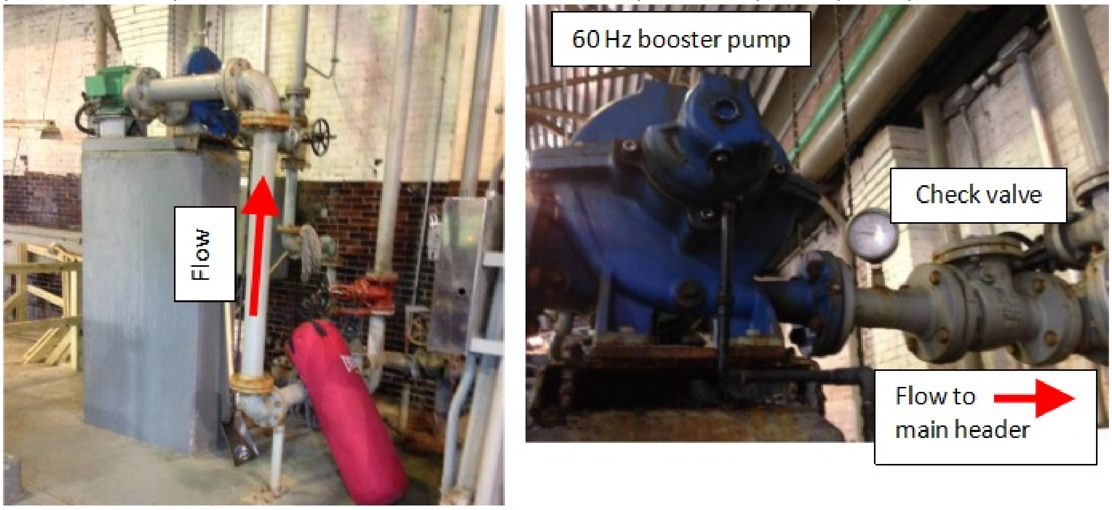
"Water pressure" city water inlet at DPS #7: penetration through floor (view looking north)

The transmitter is located upstream of three branches on the water system. Two of the branches - to the 25 Hz booster pump and to the booster pump bypass - have their valves closed and are thus isolated. The third branch leads to the 60 Hz booster pump:



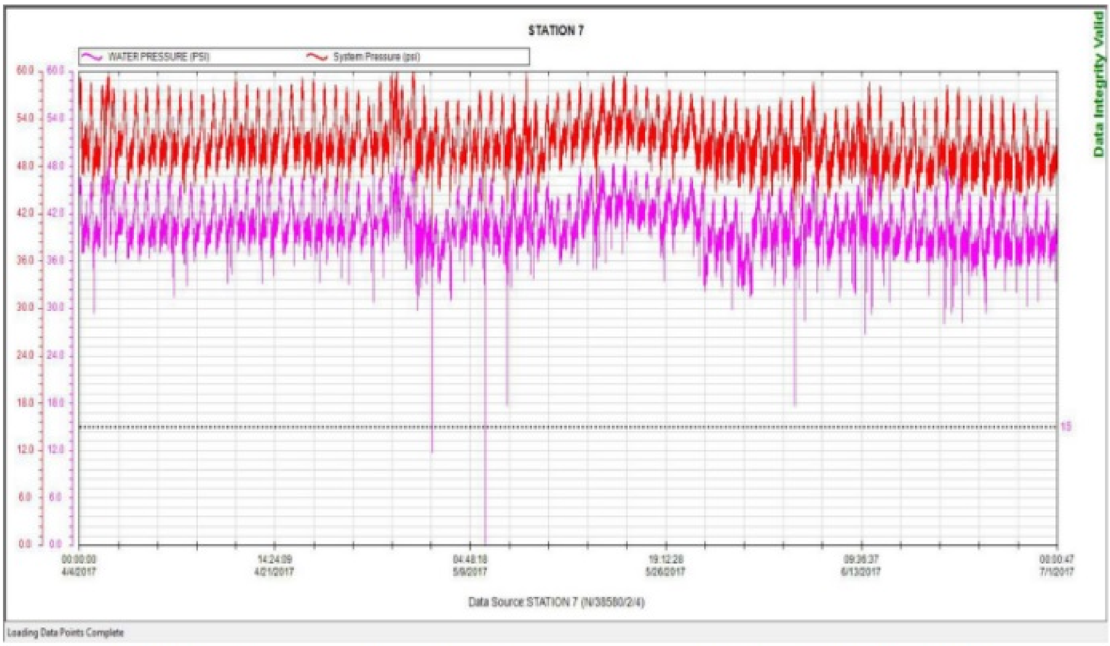
Vicinity of "water pressure" transmitter at DPS #7

Downstream of the 60 Hz booster pump is a check valve which serves to isolate the "water pressure" portion of the system from the rest of the station's water, provided by the "system pressure" inlet:



DPS 7 "water pressure" piping: 60 Hz booster pump

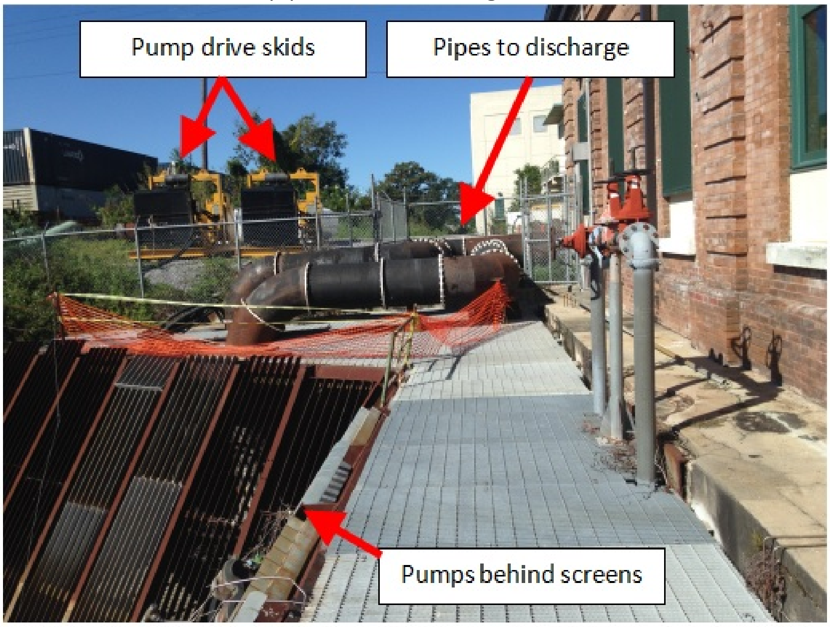
This isolation occurs because the "system pressure" at DPS #7 is always a great deal higher than the "water pressure," so the check valve only opens when the booster pump is activated. Otherwise, "water pressure" stays about 10 psi below "system pressure:"



DPS #7 water pressure (purple) and system pressure (red) from 4/4/17 to 7/1/17

The likely reasons for this difference - that is, the much lower pressure on the "water pressure" side of the system - are the massive water leaks on the shaft seals of both constant duty pumps. These seals are fed from the "water pressure" line. The leaks are so huge that the constant duty pump pit has water to a depth of a few feet in it, and a sump pump is permanently pumping water out of the pit and into the suction basin. Video of the pit when inundated is available here: https://app.box.com/s/szjcviq3vqo7dd86k45atgb9hlyaw451

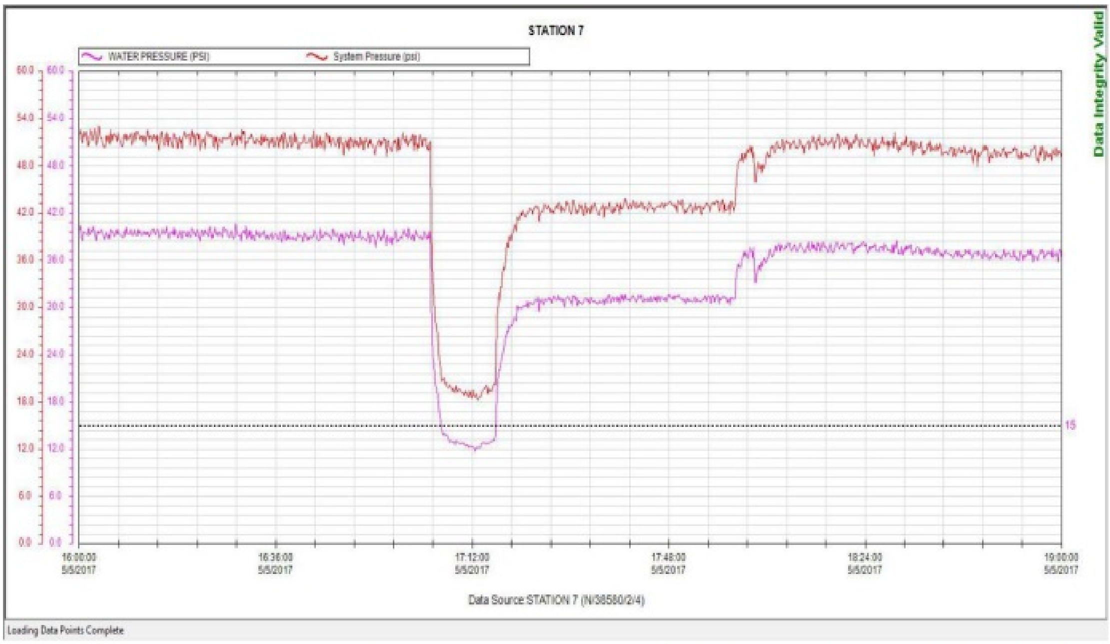
Plans call for refit of at least one of the constant duty pumps to fix this problem. To make up for the loss of pumping capacity during the refit, two temporary hydraulically-actuated axial pumps have been placed in the suction basin and piped to the discharge basin:



DPS #7: Temporary pumps to make up for capacity loss during constant duty pump repairs

However, until those repairs take place, the "water pressure" side of the station water system will have a pressure below the actual local city water pressure. It is possible it is as much as the current difference - about 10 psi.

So when the DPS #7 "water pressure" transmitter dipped below 15 psi on the afternoon of May 5, 2017, as seen on this chart:

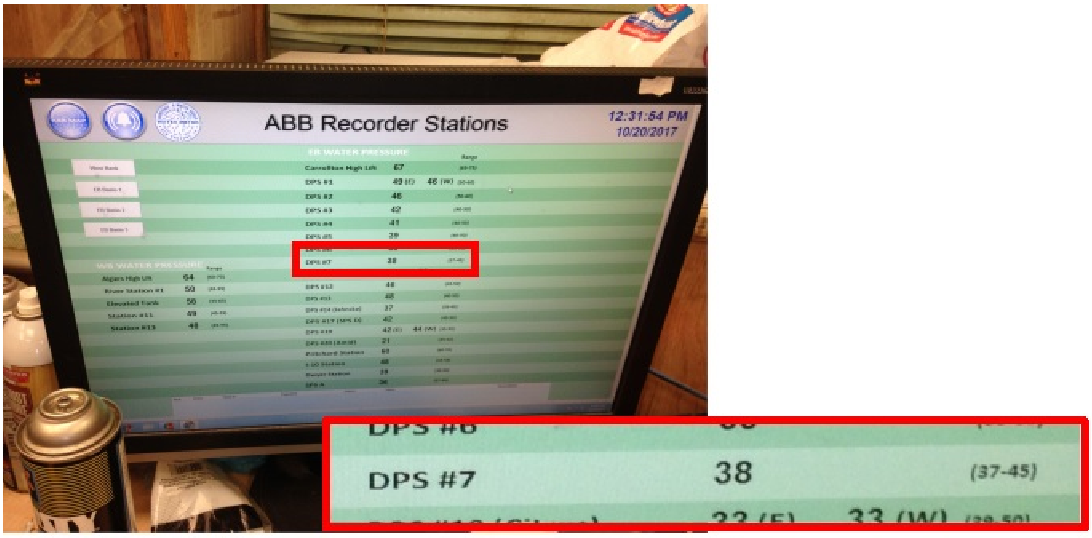


DPS #7 water pressure (purple) and system pressure (red) on May 5, 2017, from 4 PM to 7 PM

it was more a reflection of the location of the "water pressure" transmitter combined with the constant duty shaft seal leaks, and less a reflection of a local city water pressure reaching below 15 psi.

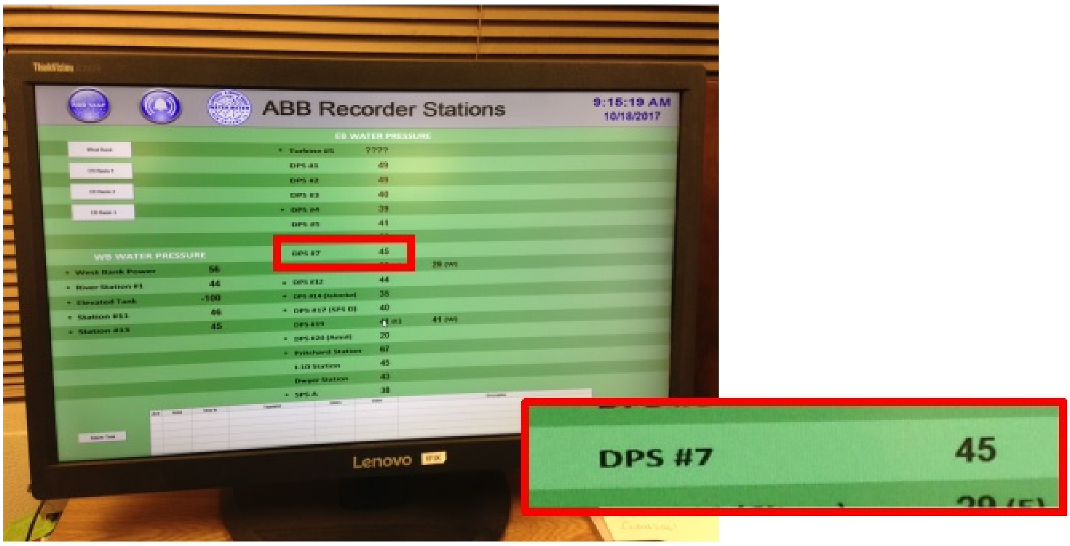
Nevertheless, like data at DPS #1 on May 5, what is of interest is not the details of why the DPS #7 "water pressure" may inaccurately reflect local city water pressure, but whether Board decisionmakers were aware of the fact that it may not. In this, they may be handicapped by their own systems.

Interestingly, the DPS #7 pressure chosen for display on the High Lift SCADA screen appears to be the somewhat inaccurate "water pressure." We know this because of the reading shown in the photo (38 psi, verified against the SCADA data collected at the time of the photo), and the acceptable range shown next to it (37-45 psi, which is the normal range for "water pressure" at DPS #7):



DPS #7 "water pressure" shown on High Lift SCADA display

However, the reading used on the Central Control screen is from the DPS #7 "system pressure" transmitter (verified against the SCADA data collected at the time of the photo):



DPS #7 "system pressure" shown on Central Control SCADA display

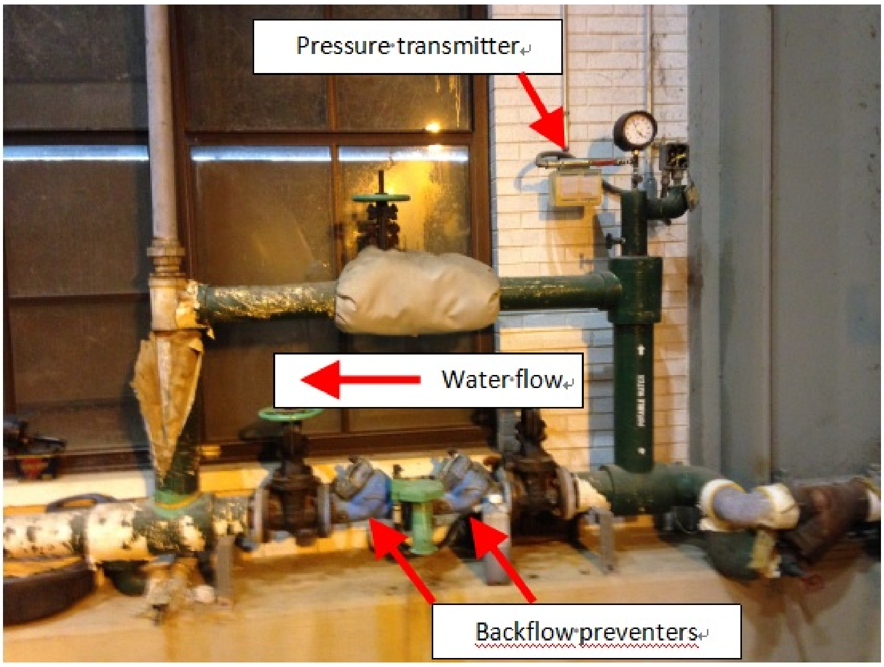
Displays on the same network are showing two different pressure readings from the same station. Only one reading - the one shown at Central Control - is likely truly reflective of local city water pressure near DPS #7.

This error brings into question exactly which transducers are being displayed across all the SCADA water pressure monitors used by the Board. It is unknown to which data decisionmakers have access, and whether that data is truly representative of local water pressure in the neighborhoods near those stations. This makes the question of how decisions are made during low city water pressure events even more salient.

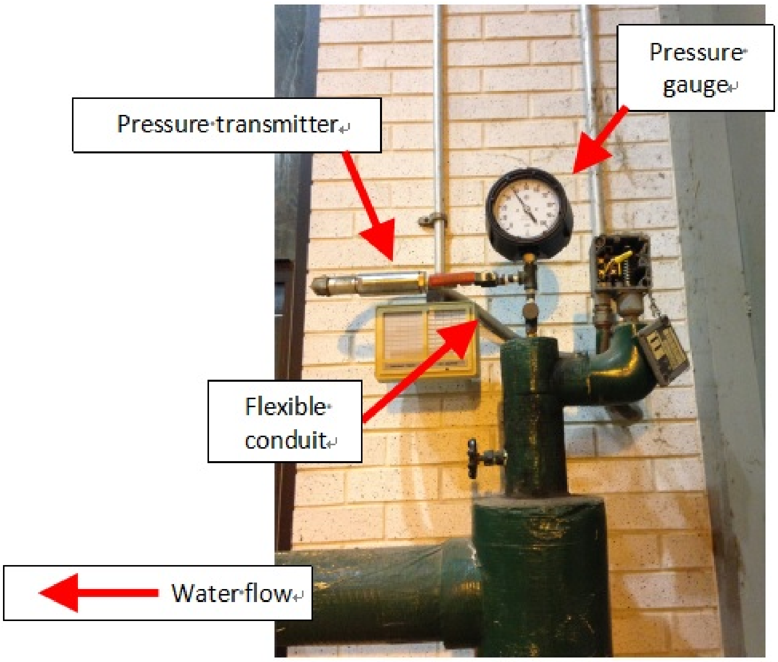
DPS #10

DPS #10, also known as the Citrus Station, is a more modern station located on the New Orleans East lakefront at 9600 Hayne Boulevard. It was built in the early 1980's. Its' two water inlets have pressure

transmitters labeled "East H2O" and "West H2O" in the SCADA system. The transmitter installations are well done. The transmitters are placed upstream of the backflow preventers with provision for isolation during maintenance, pressure gauges are installed immediately adjacent to the transmitters, and the transmitter cabling is enclosed in flexible conduit:

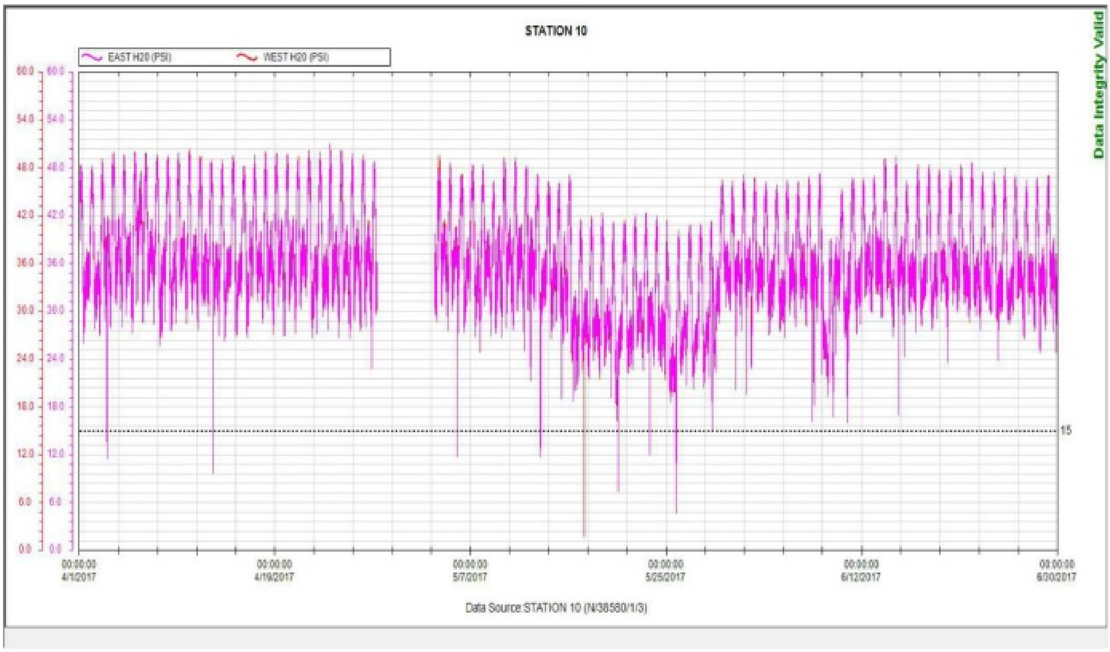


DPS #10 west city water inlet



DPS #10 "West H2O" pressure transducer installation

To a degree not seen at most other pump stations, the two inlets' pressures mirror each other very closely. Examining the data from April 1 to June 30, one can see so little variation between the two values, that it is nearly impossible to distinguish the two different colors on the chart:



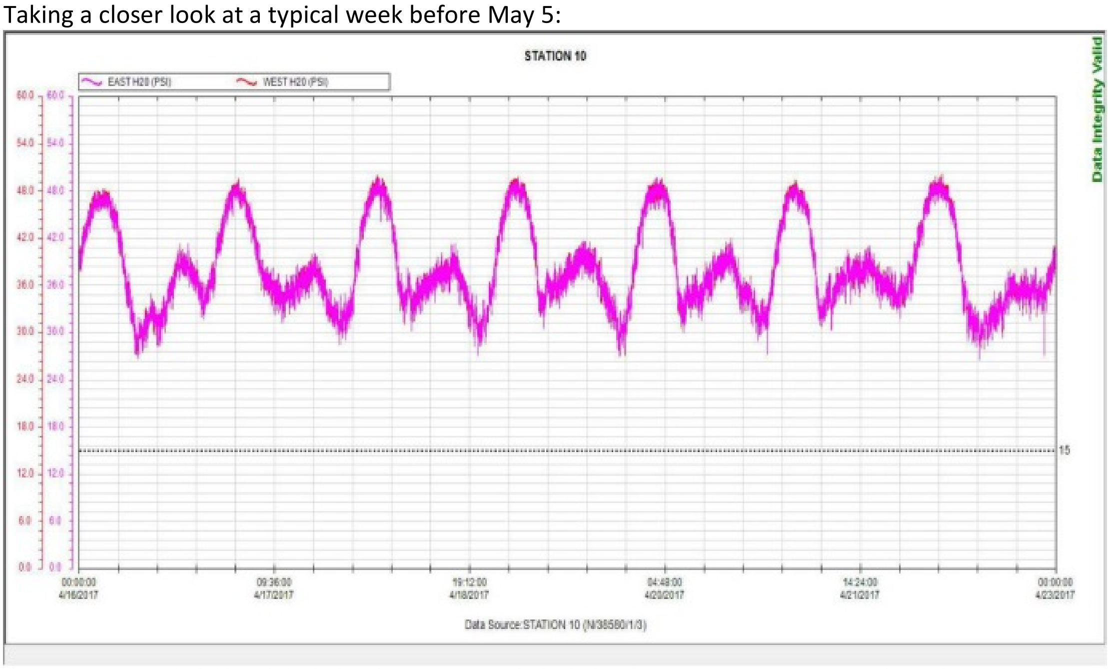
DPS #10 East H2O (purple) and West H2O (red) from 4/1/17 to 6/30/17

During this period, like at other stations, there appear to have been pressure problems. For example, as at DPS #1, SCADA data for water pressures was lost between April 28 and May 3. No explanation for this loss is known.

And as at DPS #5, water pressures dropped to unusually low values between May 15 and May 28. This phenomenon was also seen at DPS #20. Water distribution pump logs and Central Control logs do not yield any obvious explanation for this change in city water pressure among three New Orleans East stations.

Neither of these problems were in effect on May 5, 2017.

Taking a closer look at a typical week before May 5:

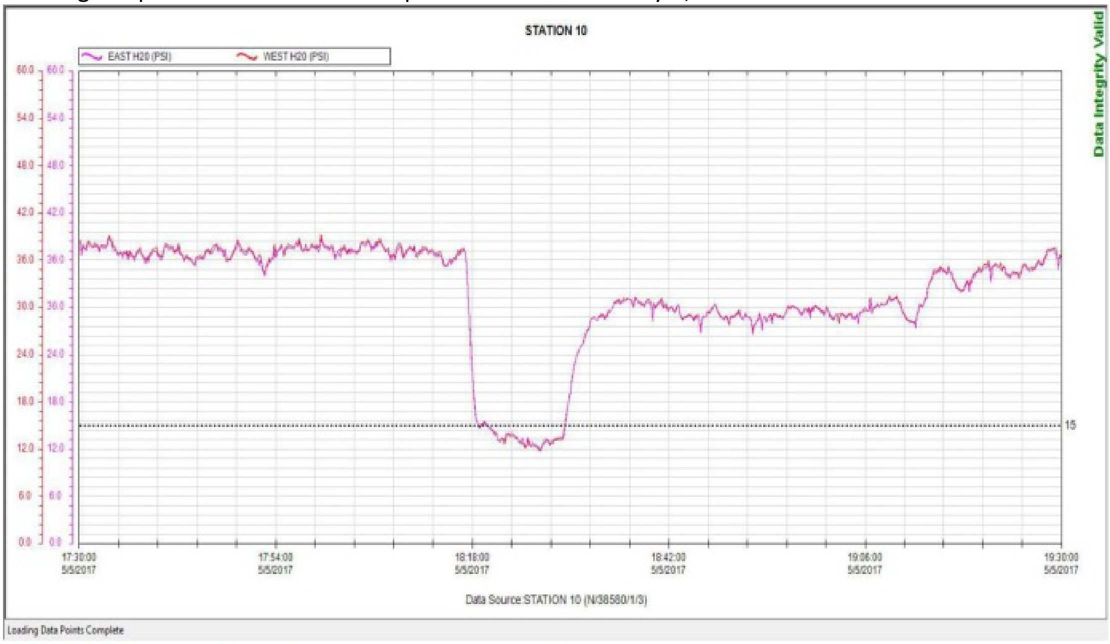


DPS #10 East H2O (purple) and West H2O (red) from 4/16/17 to 4/23/17

As one can see, there is near total overlap between the East H2O and the West H2O readings. Also notable are the relatively low pressure readings, typically hovering around the high 30's or low 40's depending on the time of day. A survey of Fridays leading up to May 5 shows typical pressure readings at 5 PM of about 37 psi. On May 5, the pressure at 5 PM was 36.0 psi for East H2O and 36.6 psi for West H2O, or completely normal. A site survey of the station showed agreement on a local pressure gauge with the transmitted value for West H2O. There do not appear to be any serious water leaks at the station which would drag the pressure down.

All of this argues for both of DPS #10's pressure transmitter values to be taken as valid and representative of local city water pressure on May 5, 2017. Please note the timestamps for DPS#10 appear to be off by about an hour, but such discrepancies are typical in systems with multiple clocks; they are very rarely synchronized. The time does not affect the pressure reading from the transmitters.

Viewing the pressure transmitter outputs for DPS#10 on May 5, 2017:



DPS #10 East H2O (purple) and West H2O (red) on May 5, 2017

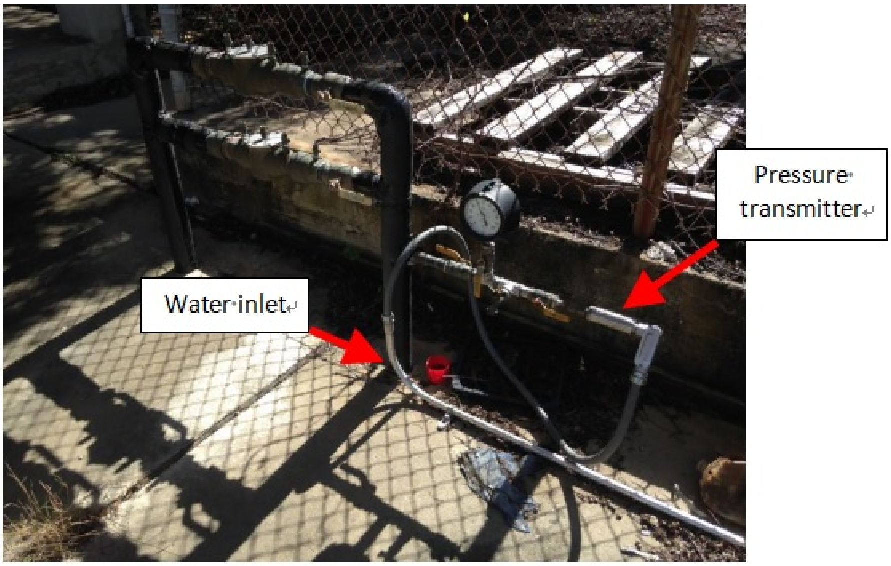
The pressure transmitters at DPS #10 are Viatran model 570's with a range of 0-75 psi. Considering the same +/- 0.4 psi error on a full scale of 75 psi as calculated above in the section on DPS #5, the time spent below 15.4 psi for each water inlet on May 5, 2017 was:

East H2O: 9 minutes, 43 seconds
West H2O: 9 minutes, 43 seconds

DPS #20

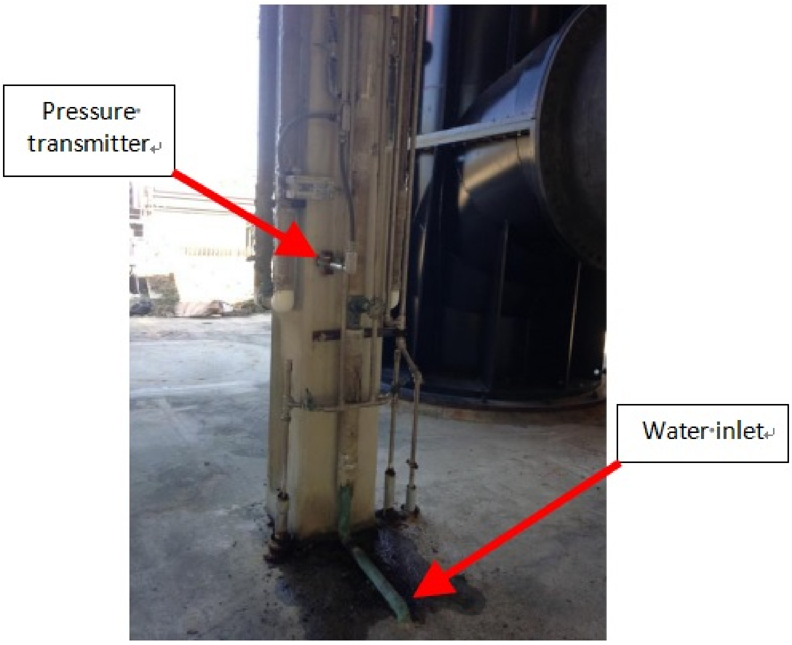
DPS #20, also known as Amid Station, is a more modern station located on the Gulf Intracoastal Waterway near the south end of Jourdan Road. It houses two vertical pumps with water seals. There are two water inlets to the station, called "water pressure" and "system pressure" in the station's SCADA system. Historically, "water pressure" has run much lower than "system pressure." In the months leading up to May 5, "system pressure" averaged around 46 psi, while "water pressure" averaged around 34 psi.

The pressure transmitter for "system pressure" is located near the steps up to the control room, upstream of twin backflow preventers:



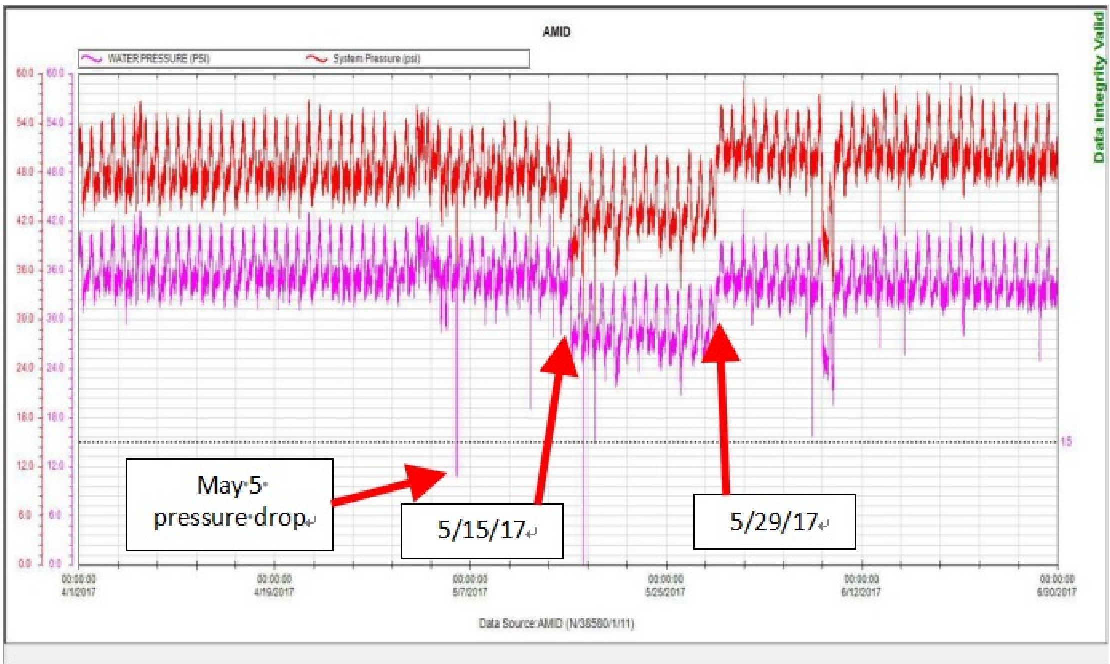
DPS #20 city water inlet, labeled "system pressure" in station SCADA system

The pressure transmitter labeled "water pressure" is located just downstream of the penetration through the slab for the other inlet, near the center of the station below the operating room:



DPS #20 city water inlet, labeled "water pressure" in station SCADA system

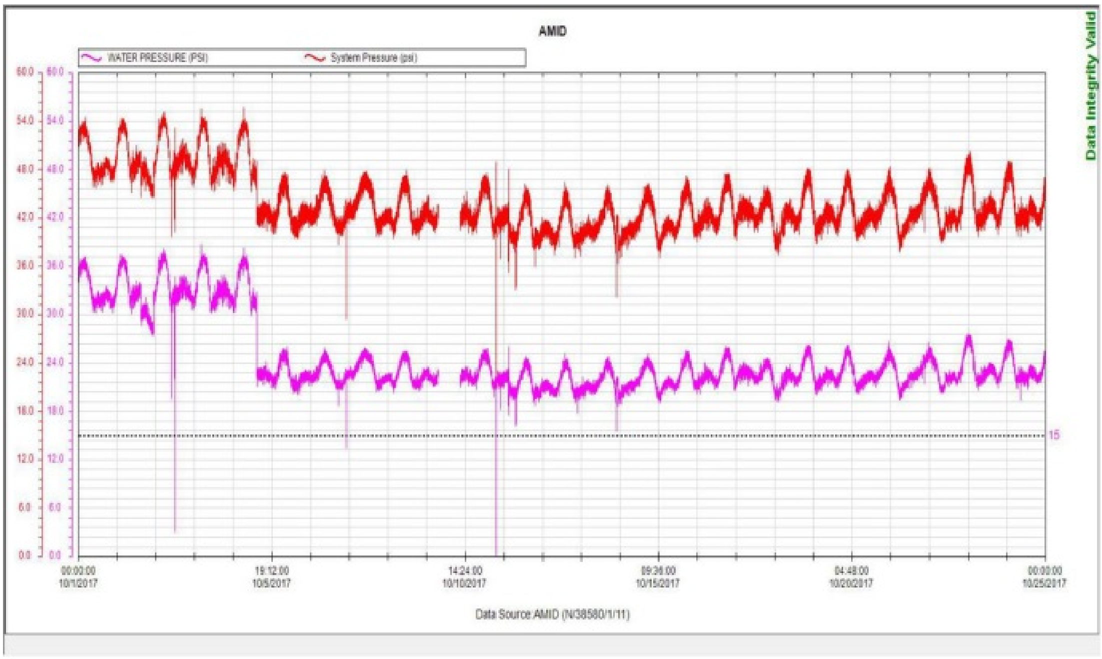
As noted above, the pressure transmitter for "water pressure" historically reads much lower than that for "system pressure:"



DPS #20 "water pressure" (purple) and "system pressure" (red) from 4/1/17 to 6/30/17

The chart for DPS #20 exhibits some of the same problems as other stations. There was a sharp drop in water pressure on May 15 which was not recovered until May 29 (nearly the same timespan as for DPS #5 and DPS #10). Also, while not as prominent as at other stations like DPS #7, there appears to have been volatility in the pressure readings on May 3 and May 4. Neither of these problems were in effect on May 5.

But the distinguishing characteristic of the pressure readings at DPS #20 is the diminished pressure read by the transmitter labeled "water pressure." This section of water piping directly feeds the water seals on the two drainage pumps. The "system pressure" leg feeds something else, probably the control room facilities. I can only surmise there is a substantial leak somewhere in the "water pressure" portion of the system, or the pressure in that section is being kept artificially low. When the station was visited in late October, pressure on the "water pressure" portion of the system was running even lower than in the spring: in the low 20's. The pressure had been that low since early October, when it dropped at the same time as "system pressure:"

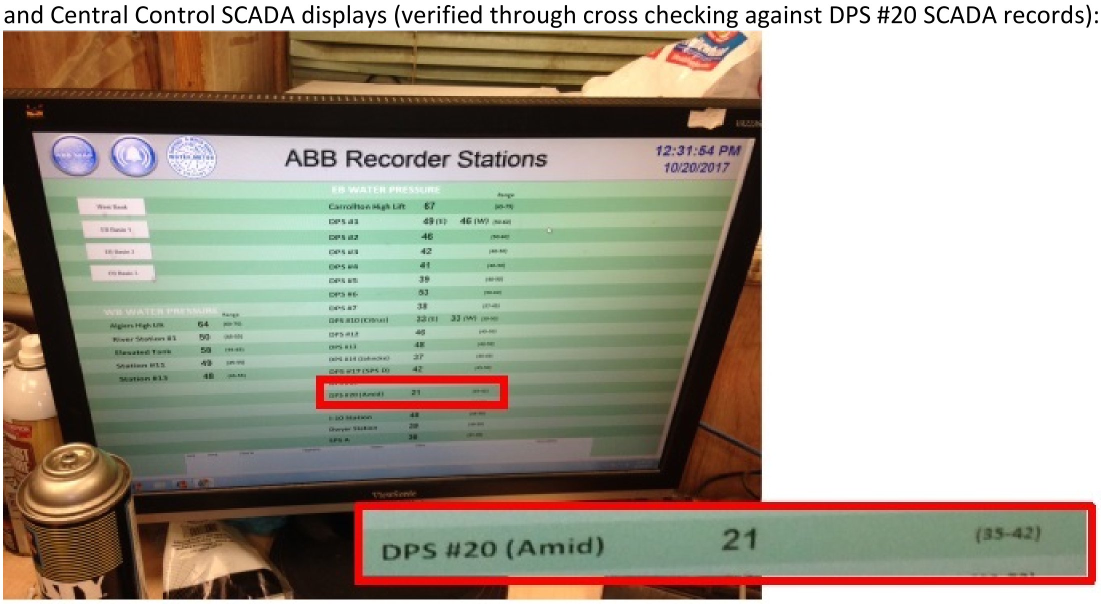


DPS #20 "water pressure" (purple) and "system pressure" (red) from 4/1/17 to 6/30/17

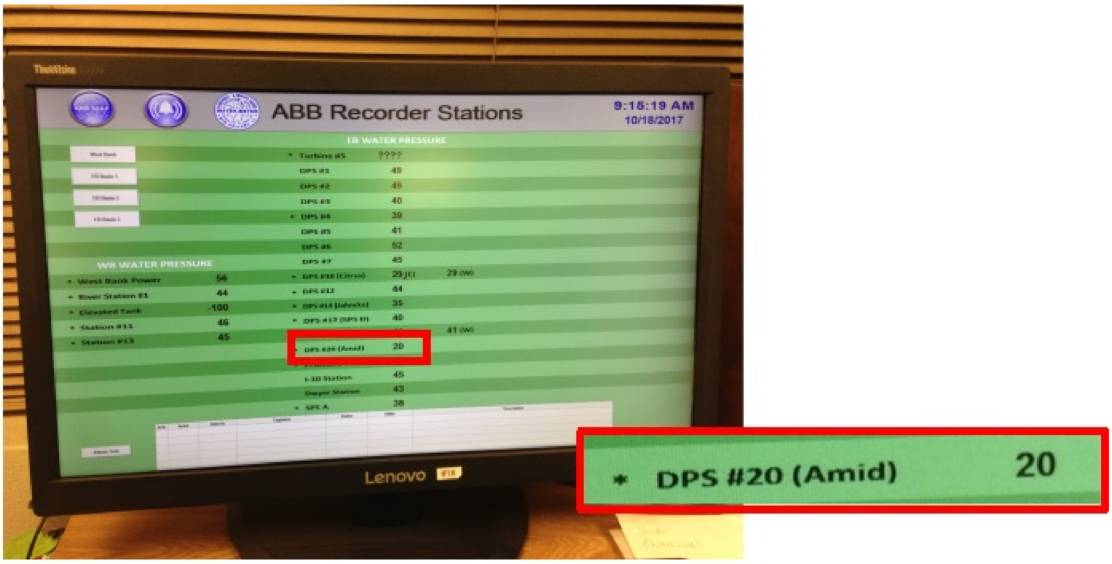
While it is conceivable that the city water pressure from the "water pressure" leg into the station is actually in the low 20's, it seems unlikely. 22 psi is hardly enough pressure to do anything, and one has to wonder if it is truly adequate for the station's needs, especially the pump that was recently repaired under a Board emergency declaration.

Therefore, given the large historic gap between "system pressure" and "water pressure" at DPS #20, it does not seem warranted to consider "water pressure" there as representative of local city water pressure.

However, as with DPS #1 and DPS #7, the same question exists regarding use of DPS #20 "water pressure" by Board decisionmakers during a low water pressure event: is there a sophisticated understanding of whether "water pressure" at DPS #20 truly represented local city water pressure? It is not an academic question, since the DPS #20 "water pressure" is the one used on both the High Lift and Central Control SCADA displays (verified through cross checking against DPS #20 SCADA records):



DPS #20 "water pressure" shown on High Lift SCADA display



DPS #20 "water pressure" shown on Central Control SCADA display

Once again, as with DPS #7, it appears that a non-representative water pressure has been chosen to portray local city water pressure to senior Board staff. There is, of course, a chance that the "water pressure" inlet at DPS#20 truly does run so low as to almost routinely approach 15 psi. If that is the case, there is a serious problem with the local water pressure in the area. However, the much higher pressure from "system pressure" makes that chance quite small.

Summary of stations with pressure readings near or below 15 psi on May 5, 2017

Of the minimum five stations which captured water pressure readings below 15 psi on May 5, 2017, two can be considered as possessing valid, representative data which likely reflects the city water pressure in the surrounding neighborhood. When one takes into account the accuracy of the pressure transmitters themselves, the threshold rises to 15.4 psi.

The two stations are:
DPS #5: "water pressure" transmitter recorded pressure less than 15.4 psi for 3 minutes and 10 seconds.
DPS #10: Both "East H2O" and "West H2O" transmitters recorded pressures less than 15.4 psi for 9 minutes and 43 seconds.

While pressure readings below 15 psi at three other stations - DPS #1, DPS #7, and DPS #20 - may not have been representative of local water pressure on May 5, it is unknown if Board decisionmakers were aware of that at the time. In addition, pressure readings at two other stations - DPS #3 in Mid-City and DPS #4 in Gentily - came within 2 psi of the 15 psi threshold during the May 5 event.

A search of the Sewerage and Water Board's online press release archive, local media sources, Twitter and Facebook did not find any evidence of the issuance of a precautionary boil water advisory on May 5, 2017.

Water distribution pump pressure losses are common

According to the operational logs for the water distribution pumps, the turbines, Central Control, and the drainage pumping stations, citywide drops in water pressure are quite common. In 2017, citywide water pressure has dropped below the High Lift low water pressure alarm limit of 65 psi at least 64 times.

While only one pressure drop this year was as deep as the May 5 event - the one that resulted in the September 20 boil water advisory - many have been quite large and could have easily gotten worse.

For example, on May 12 - just a week after the May 5 pressure drop - a 60 cycle power outage at the New River Intake station appeared to trigger a water pressure loss of about 26 psi within the plant. Some drainage pump stations registered water pressures between 21 and 22 psi that day.

Pressure drops similar to the May 12 event - a drop of greater than 20 psi as measured at High Lift - have happened at least twelve times in 2017. None were planned.

January 30
22.5 psi loss, attributed to 25 Hz Claiborne pump 4 tripping out.

February 9
22 psi loss, attributed to trip of A pump during restart following planned steam outage.

February 22
Two losses back to back, one of 24 psi,. the second of 22 psi. Both attributed to loss of 25 Hz Claiborne pump 1 during work on Claiborne battery bank by S&WB electricians. Work was troubleshooting of problems with feeder CPB, which were traced to dead batteries.

February 24
22 psi loss, attributed to trip out of 25 Hz Claiborne pump 1

March 8
Two losses back to back during the three day crisis that included the loss of all 25 Hz turbines. As turbine 5 was failing in the evening, Panola 2 pump failed and 60 Hz Claiborne pump 2 had to be brought on line, resulting in a 22 psi drop. Immediately following, power had to be found to keep 25 Hz Claiborne pump 1 running. Frequency changer 4 was used to power Claiborne pump 1. During the time required to start the frequency changer and transfer the power load from turbine 5 before its shutdown, pressure was down by 26.5 psi.

May 5
Detailed above.

May 12
Detailed above.

July 9
First of two back to back losses. Attributed to loss of both pumps at Panola station. Both Panola pumps had been brought online as backups during triage of Claiborne pump 3 (placed on emergency use only on July 7) and turbine 1 (ejectors clogged with carryover and welded rheostat brushes found on July 9). The trip of Panola pump 2 while on its 60 Hz motor resulted in a 20 psi drop. The trip of Panola pump 1 while on 60 Hz power resulted in a 16.5 psi drop. Only the first drop is included in the total above.

September 20
Water distribution pumps "in" were pumps A and B, 60 Hz Claiborne pump #2, and 60 Hz Panola pump #2. 60 Hz turbine 6 was powering both 60 Hz pumps. The turbine went down unexpectedly at around 7:23 AM, taking both 60 Hz pumps with it and resulting in a massive loss of citywide water pressure. Water pressures at most drainage pump stations fell well below 10 psi. This was the only water pressure loss worse than May 5. A precautionary boil water advisory was issued for the east bank. The advisory was lifted the next morning.

September 23
Pressure drop of 21 psi, the fourth pressure drop in a 90 minute span between 5 PM and 6:30 PM (others were 6, 8.5, and 12 psi). Cause is unknown, though problems were noted with bearing temperature on Panola pump 2, and it was eventually shut down in favor of Claiborne pump 2.

The 12 incidents enumerated above are merely the largest citywide pressure drops in the water distribution system in 2017. Description of all the citywide pressure drops would make this report unnecessarily lengthy. Suffice to say the water distribution system will be making heavy use of the water towers when they are brought online. The towers will smooth out not only unanticipated upsets, but also pressure drops brought on by routine changes in pump use.

Conclusions and recommendations

Conclusion 1: On May 5, 2017 a very large citywide water pressure drop occurred around 5:40 PM due to the simultaneous loss of two of four water distribution pumps, specifically pumps "A" and "B." The drop was large enough that - according to Board SCADA data collected at drainage pumping stations - water pressure in some neighborhoods dropped below the state-recommended 15 psi threshold for initiation of a precautionary boil water advisory. No such advisory was issued.

Recommendation 1a: Review all documentation surrounding the events of May 5, 2017 including (but not limited to) raw data from all sites with water pressure transmitters, written logs, emails, texts, and interim and final internal S&WB reports. Discussions with S&WB staff indicate such reports exist. Confirm the decision not to issue a boil water advisory was either correct or incorrect.

Recommendation 1b: Expand the review to any other events during which east bank water pressure could have dropped below 15 psi in prior years and a boil water advisory was not issued. A general guideline for such events is that at least two water distribution pumps would have failed simultaneously. West bank water pressure drop incidents should also be reviewed.

Recommendation 1c: Within 15 days, conduct a comprehensive review of the decision process for whether to issue a boil water advisory with particular emphasis on data quality and alarm notification timeliness. Issue recommendations for improvements with a defined schedule and assign personnel to be responsible for implementation. Ensure recommendations are implemented or scheduled for implementation before departure of Interim Emergency Management Team on November 30, 2017.

Conclusion 2: Electrical power to the control cabinet for pumps A & B remains vulnerable. The programming of alarms related to loss of either the 60 Hz AC or the DC battery backup in the cabinet - which led to the May 5 shutdown of both A & B pumps - has been corrected. But the larger problem of having both turbine controllers in the same cabinet with a common power supply - even one with battery backup - still remains. A and B pumps are the absolute workhorses for the city's water distribution system: pump B has run every day this year, and pump A has only been down for a single day. They should be as independent as possible to avoid massive pressure drops.

Recommendation 2: Provide separate power supplies for each turbine controller for A and B pumps. Each should also be backed up independently, and each should have its own HMI to prevent errors. Also, alarms from each HMI should be sent out beyond the pump room. These changes could be incorporated into the boiler room upgrade project which will be kicking off soon.

Conclusion 3: Online monitoring of city water pressure at drainage pump stations and other locations equipped with ABB SCADA monitors appears to be error prone. Data sent from some stations is likely not representative of city water pressure in local neighborhoods. Data is not consistently presented within the monitoring network, with some stations using different data sources on different monitors. In other cases, the same data is presented with different labels. Educated use of the data by key stakeholders in a low water pressure crisis is impacted by this confusing scheme. Given the large number of water pressure drops throughout the year, the consequences upon decisionmaking could be frequent and deleterious.

Recommendation 3: Assign an engineer to do a complete survey of all water pressure monitoring points throughout the system and all SCADA displays which collect the data. Compile findings for submission to the Interim Emergency Management Team within 15 days. Correct any deficiencies such as use of non-representative data, mistaken labeling, and lack of consistency from display to display. Implementation or scheduling of implementation of fixes should be complete by the time of the I-Team's departure on November 30.

Conclusion 4: Alarming and notification of low water pressure conditions is fragmented and vulnerable to response delays. The key alarm point for the entire system - the High Lift control room -

contains a switch which can turn the alarm off. The room can also be unmanned quite often, and low water pressure alarms are not transmitted within the rest of the powerhouse via strobes or audible alarms. This means a low water condition could occur when the High Lift operator could not respond in a timely manner. The SCADA monitoring and alarming of water pressure can be lost during a 60 Hz power outage, leading High Lift and Central Control operators to ignore the system and rely instead on manual gauges, which can be notoriously unreliable themselves. SCADA water pressure terminals are not available at the three water distribution pump stations at the Carrollton plant. Overall, there is not a robust, broad, and deep scheme for alerting all relevant personnel quickly to a systemwide condition which could directly affect many of the city's most vulnerable residents.

Recommendation 4a: Remove the low water pressure alarm silence switch in the High Lift control room.

Recommendation 4b: Expand notification of low water pressure alarms throughout the powerhouse to include strobes or horns to allow personnel to be alerted from any location to such an alarm.

Recommendation 4c: Revise the power supply for the SCADA display and the water pressure chart recorder in the High Lift control room so they do not go down during a 60 Hz power loss. Investigate whether the main low water pressure alarm is also susceptible to such power losses and - if so - also build redundancy into its power supply.

Recommendation 4d: Program the low water pressure alert system - which now generates emails - to generate texts as well. Expand the list of personnel alerted by such alarms to encompass all senior leadership and all relevant personnel in the powerhouse, in maintenance, and in operations.

Recommendation 4e: As part of the SCADA survey recommended above, ensure all SCADA water pressure terminals generate audible and visual alarms as programmed. Test such alarms at least semi-annually.

Recommendation 4f: Expand the placement of SCADA water pressure terminals to Claiborne Station, Panola Station, and the pump A & B room.

Conclusion 5: Low water pressure events across the system are quite frequent. In 2017, there have been at least 64 instances of water pressure dropping below the single High Lift low pressure alarm point of 65 psi. A dozen were substantial, involving a drop of 20 psi or more. Others were minor. The sheer volume of such events - combined with a single very conservative alarm point of 65 psi - can lead to complacency and can obscure truly serious events from merely routine ones. It is also the likely reason the low water pressure alarm silence switch was installed in High Lift.

Recommendation 5: As part of the review of water pressure monitoring throughout the system, consider implementation of a two tier alarming scheme. The first tier would be a "warning" which could encompass minor pressure drops, while the second tier would be an "alarm" which would encompass more serious pressure drops and which would require focused action. More sophisticated notification can accompany such a scheme so that the truly important events are given the attention they deserve.

Conclusion 6: At some pump stations across the city, leaks and other operational impediments prevent proper functioning of the city water supply system to equipment which relies on water, including vacuum pumps and drainage pump seals. Examples include the huge seal leaks on the constant duty pumps at DPS #7 and the elimination of the 25 Hz booster pump at station 6 (detailed in a prior report). This has a side effect of causing faulty information to be reported to decisionmakers during low water pressure events.

Recommendation 6: Causes for low water pressure within stations must be fixed so that the quality of information provided to Board leadership is high. Assign an engineer to work with the plumbing group to review water system maintenance records for at least the stations with SCADA pressure

outputs. Compile a master list of deficiencies with estimated repair costs and durations for review by the Interim Emergency Management Team. Identify and fix problems on water lines which are causing low water pressure. This includes repair or replacement of booster pumps through the system. This effort should be coordinated with the reviews recommended above and the recommendations regarding pressure transmitters below. Implementation or scheduling of implementation should be complete by the time the I-Team departs on November 30.

Conclusion 7: Installation of pressure transducers at drainage pump stations is inconsistent. While some transducers are well installed, others leave much to be desired. Placement of transducers, use of pressure gauges, and protection of transducer cabling are all issues.

Recommendation 7a: For transducers located far downstream in water inlets, move the transducer as far upstream as possible, ideally before backflow preventers. Locate tranducers inside by utilizing pressure taps and wall penetrations off externally mounted water lines. The installation of the pressure transducer at the northwest corner of DPS #7 is a good example.

Recommendation 7b: Install pressure gauges on same branches as transducers to allow field verification. Gauges should have a range of double the pressure range of the transducer.

Recommendation 7c: Enclose all pressure transducer cabling in flexible conduit to prevent damage to wires and accompanying signal degradation.